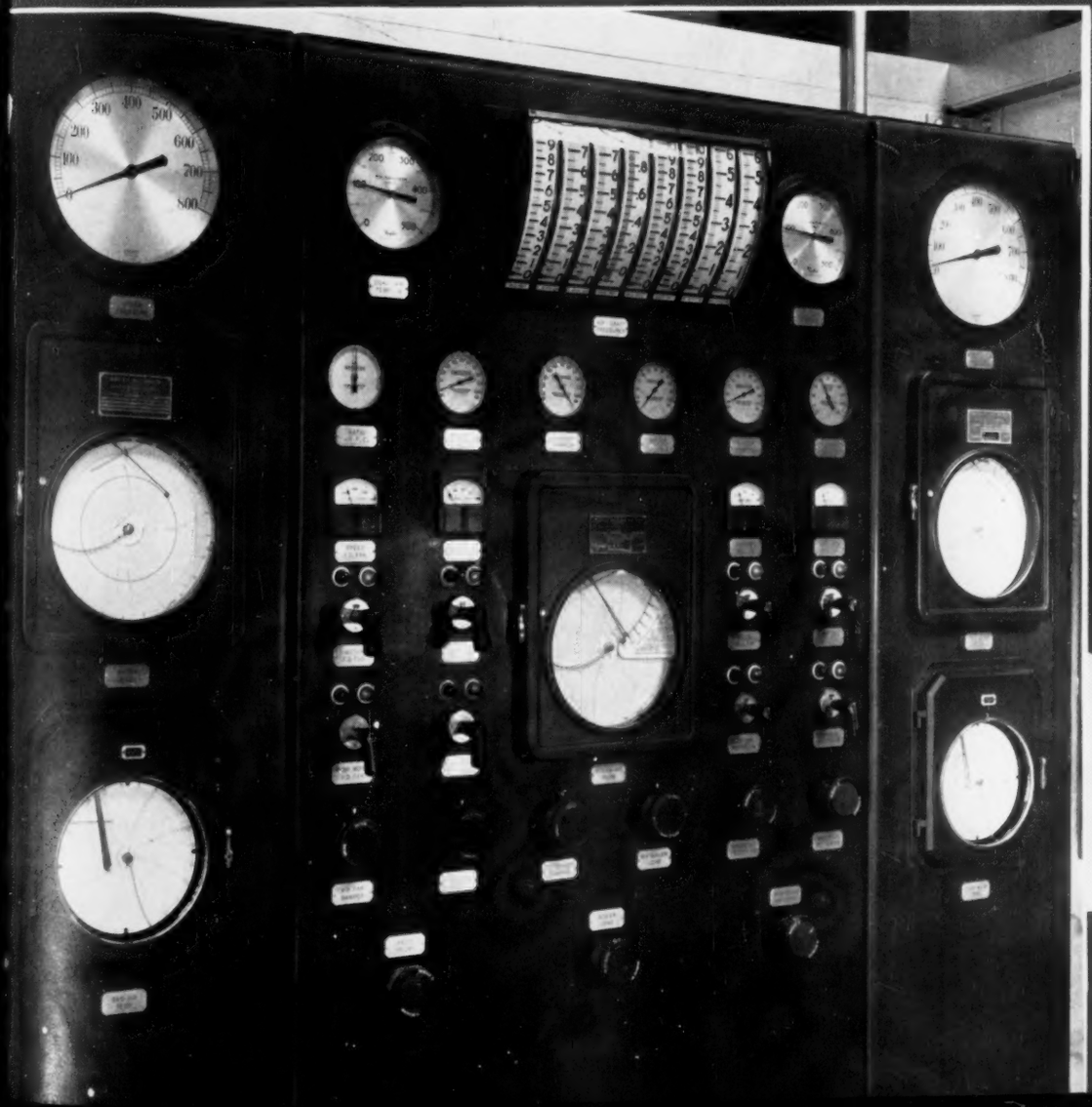
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL



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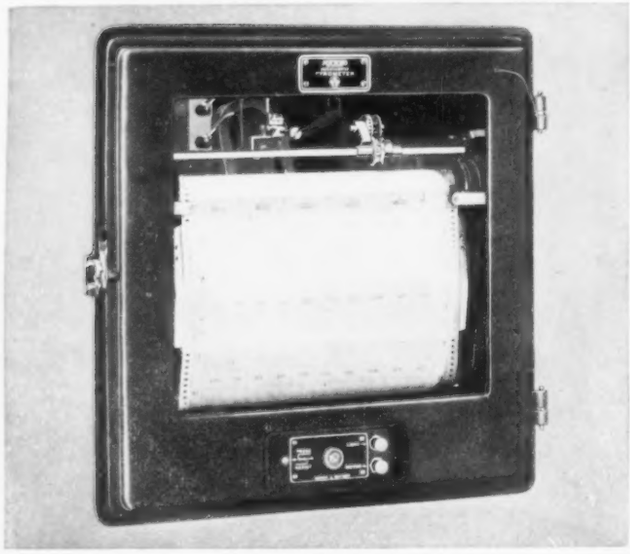

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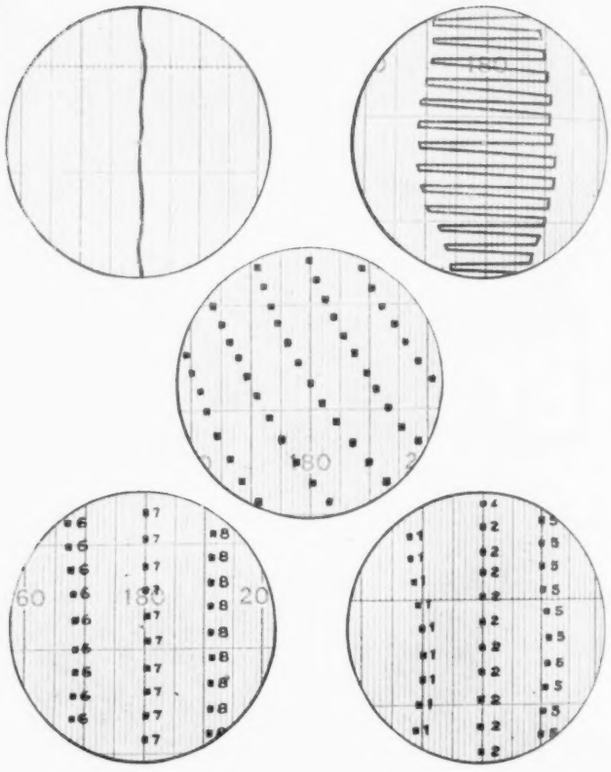

. . . the Quality is Certified by FOXBORO . . .

Do you want a single continuous temperature record, or as many as eight different records on one chart? You can have exactly what you need in this Foxboro Potentiometer Pyrometer. It's one of the features that causes hosts of users to specify this accurate and dependable recorder.

Rapid response to thermo-couple changes. A dependable mechanism which is mechanically and electrically simple. These qualities make for enduring accuracy and sensitivity. Time exacts slight toll of Foxboro Potentiometer Recorders.

These and many other profit-producing qualities are described in Bulletin 190-1. Write for a copy.

THE FOXBORO COMPANY
46 Neponset Avenue
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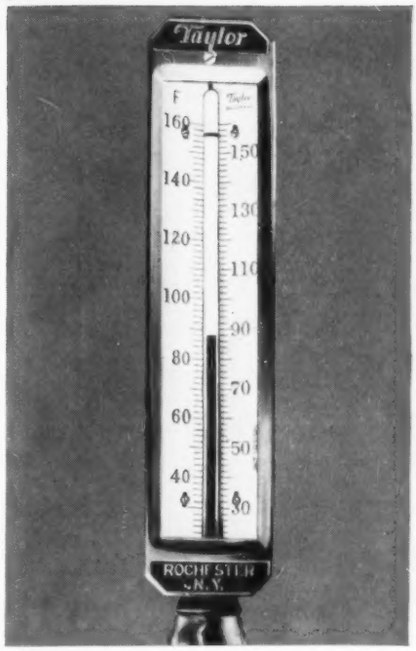
FOXBORO PYROMETERS

ACCURACY FOXBORO *RESPONSE*

SQUINT at your thermometers

Read them now with both eyes open more easily, more accurately, at greater distances with—**NEW TAYLOR "BINOC" TUBING**



THIS IS A PICTURE *of the latest Taylor Industrial Thermometer with the new Taylor* "BINOC" *Tubing. Do not attempt to judge anything from this picture except the modern, clean-cut design and appearance of this new instrument. Test the actual instrument yourself and prove its superiority.*

"REMARKABLE!" "Wonderful!" "A really big development!" "The greatest advance of its type in thermometer history."

Unusual praise indeed. But it is praise of an unusual product.

With "Binoc" Tubing, Taylor makes previous industrial thermometers obsolete.

"Binoc" Tubing ends squinting with one eye. It does away with "approximately accurate" readings. It gives thermometers that can be read *with both eyes open*. It gives *Binocular Vision.*

It supplies a thermometer with double the angle of vision—with two to five times the visibility of previous thermometers. And does it without sacrificing high magnification.

It eliminates bore reflection, which has been one of the greatest handicaps in making accurate readings on any thermometer up to now.

All of these amazing advantages result from correct application of the principles of light reflection. A triple lens construction assures the wider angle of vision, greater concentration of light, and the necessary light reflection on the mercury column. *In other words, it gives a thermometer that is many times easier to read.*

Test for yourself the things we have said here. Prove also that Taylor Industrial Thermometers equipped with this new tubing are the most efficient and easy to read available today. A Taylor Representative will present the complete story, and let you make a test with your own eyes so that you can be the judge. If you want a demonstration quickly, write at once to Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

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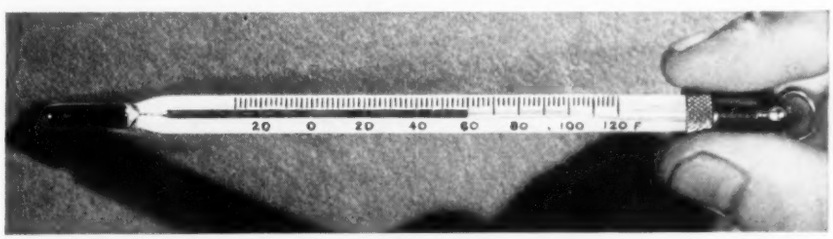
THERMOMETERS
with "BINOC" *tubing*
REG. U. S. PAT. OFF.



TEST "BINOC" IN YOUR OWN THERMOMETER

BE ONE of the first to get this New Taylor Engineer's Pocket Test Thermometer with "BINOC" Tubing. It is offered to you to make your own easy-reading tests. You'll find it convenient to use in scores of places. Range; 0° to 220° F. or −30° to 120° F. Fill out coupon and order the range you want. Send check or money order.

TAYLOR INSTRUMENT COMPANIES,
Dept. H-3, Industrial Sales, Rochester, N. Y.

I want to see "BINOC" Tubing. I enclose check for the Engineer's Pocket Test Thermometers (with protective case).

CHECK HERE WITH RANGE −30° to 120° F—$1.25 EACH ☐
WITH RANGE 0° to 220° F—$1.50 EACH ☐

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

CONTENTS · DECEMBER 1936

Front Cover: Boiler Instrumentation
City of Springfield, Illinois
See description on page 343

Organizing Instrument Services 331
in a typical industry
By A. G. Moon

Photoelectric Photometers and Colorimeters . 335
Discussion of characteristics—concluded
By K. S. Gibson

Testing Electric Tapes 339
Friction and rubber types
By W. H. S. Youry

Cathode-ray Tube Applications 341
The basic ones—concluded
By R. R. Batcher

Oscillographs 344
Electromagnetic class described this month
By Perry A. Borden and M. F. Béhar

John L. Hodgson 354
Obituary

INSTRUMENTS' READERS AT WORK

No. 20—Louis Nathaniel Hunter 326

NEW INSTRUMENTS 327
Indicators, recorders, controllers, inspection devices, etc., for the plant and laboratory

OTHER DEPARTMENTS, etc.

EDITORIAL COMMENT 325
INSTRUMENTS' BOOK SHELF 350
QUESTIONS & ANSWERS 352
INSTRUMENTATION FORUM 354
MANUFACTURERS' NEW LITERATURE . . . 356
ADVERTISERS' INDEX 356
BUYERS' GUIDE A8

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

From time to time your editor receives suggestions to the effect that he should go after more articles designed to appeal to high executives in industry. We could always reply that everything we print is of interest to high and low; but anyway this month's leading article seems to possess—thanks to A. G. Moon's experience—that elusive quality known as "executive appeal."

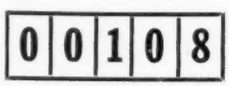
The National Bureau of Standards is dedicated to Truth, and in the conclusion of his thorough discussion of photoelectric instruments Dr. Gibson divulges facts about these devices—facts which will hurt no one but will on the contrary do good in the long run to makers and users alike.

Again we (and you) are indebted to Paul Findley, member of *Instruments'* Editorial Advisory Board and Managing Editor of *Bell Laboratories Record*, for an article originally prepared for his organization: W. H. S. Youry's disclosures on the testing of tapes.

Ralph Batcher concludes his discussion of the fundamental applications of the cathode-ray oscillograph. Next month he will start describing industrial applications.

And the beginning of a thorough discussion of electromagnetic oscillographs follows: it is of course a small portion of the long serial on Electrical Measurements and Control.

THE COUNTER READS



but it should read 109 because, although *Instruments* ends its ninth year and although $9 \times 12 = 108$, last March's issue was destroyed in the flood and had to be re-printed. But why think of past troubles when the future smiles? . . . A Merry Christmas and a Happy New Year to you all!

Too Many Bolt-tighteners

IN 1935 a shortage of skilled labor began to be reported by industries and utilities. It has grown acute in 1936. Industry itself did not cause this shortage from which it suffers, but it made it worse by discharging mature wage-earners. In 1930, '31 and '32, thousands of executives laid off hundreds of thousands of America's most competent workers, adding them to the millions whose jobs had vanished. Several million men, whose efficiency represented fifteen or twenty years of training and practice, were robbed of their skill by three or four years of idleness (or of aptitude-destroying relief work). To make matters worse, there was an almost complete cessation of the various apprenticeship systems in industry.

The shortage of skilled labor will be recognized as a major national problem when the present clash of political theorists gives way to studious observations of things as they are. President Roosevelt may have had it in mind among other problems when he circularized engineering educators:

THE WHITE HOUSE

Washington, October 7, 1936

My dear President Doherty:

Events of recent years have brought into clearer perspective the social responsibility of engineering. . . .

In respect of the impact of science and engineering upon human life—social and economic dislocations as well as advance in productive power—the facts are revealed with distressing clearness in public records of unemployment, bankruptcies and relief. The responsibility of scientists has been analyzed in noteworthy addresses such as, among the most recent, those presented at the Tercentenary Celebration of Harvard University and the meeting of the British Association for the Advancement of Science.

The design and construction of specific civil engineering works or of instruments for production represent only one part of the responsibility of engineering. It must also consider social processes and problems, and modes of more perfect adjustment to environment, and must cooperate in designing accommodating mechanisms to absorb the shocks of the impact of science.

This raises the question whether the curricula of engineering schools are so balanced as to give coming generations of engineers the vision and flexible technical capacity necessary to meet the full range of engineering responsibility. . . .

Sincerely yours,

FRANKLIN D. ROOSEVELT

Robert E. Doherty, President
Carnegie Institute of Technology
Pittsburgh, Pennsylvania

Of course there is no such phenomenon as the "impact" of science and engineering. The gradual *influence* of science and engineering has transformed prehistoric herds of cannibalistic primates into orderly human societies where babies can grow up to be Beethovens and Dantes and Rembrandts and Rodins and Einsteins and Platos—or intelligent, healthy, kindly and mutually-useful plain people. The chief aspect of the influence of engineering has been and continues to be the advance in productive power—which means more and more leisure, less and less drudgery for mankind. One of the greatest blessings of science and industry is automaticity, for it cuts down the sum total of repetitive drudgery and creates jobs for skilled workers: upstanding, law-abiding, satisfied workers. The age of Instrumentation is almost here. It will come when there are enough Instrumenticians.

Government, education and industry should join hands in an intensive program of training people for participation in a dynamic (not a standstill) industrial civilization. Since relatively few boys and girls can go to college, and since millions of adults need training (or re-training), industry must lose no time in establishing skill-developing courses *for it own workers*, too many of whom are bolt-tighteners.

Our own part having to do with skills related to instruments, we have been gathering articles setting forth how instrument men can best be trained. One such article appeared in our April 1936 issue; another will appear in our next issue . . . and there will be more.

No. 20—LOUIS NATHANIEL HUNTER

Manager of Research, National Radiator Corporation Johnstown, Pennsylvania

By M. F. BEHAR

IT is fitting that the first year of this Readers' department should end as it began, with a charter subscriber who is a department head and who passes *Instruments* among his men. Hunter has twenty-two men. We have so many readers in the National Radiator organization that to name them all would make this page look like a directory. We can't refrain, however, from reporting what a pleasure it was to meet NRC's research-minded President Robert S. Waters whose appreciation of scientific problems and whose enthusiasm for technical improvements have won him the affection of all his engineers. Nor can we refrain from paying tribute to Hunter's able assistants.

INSTRUMENTATION of NRC's RESEARCH DEPARTMENT

Recording thermometers, Chemical thermometers, Optical pyrometers, Potentiometers, Recording pyrometers, Thermocouples, Thermostated ovens.

Hydrometers, Flash point apparatus (closed cup), Flash & fire apparatus (open cup), Viscosimeter, Cloud & pour test apparatus, Centrifuge, Carbon determination apparatus, Sulphur determination apparatus, Distillation apparatus. Iodine pentoxide machine, Orsats, CO_2 recorders.

Anemometers, Manometers, Inclined draft gages.

Ammeters, Voltmeters, Watthour meters, Millivoltmeters.

Analytical balances, Laboratory scales.

Electric timers, Jeweled stop watches, Decimal timers, Electric program timers.

Hardness testers, Tensile strength testers, Ductility testers, Microscopes, Photomicrograph.

Hydrogen ion determination apparatus, Liquid meters, Gas calorimeters, Steam calorimeters.

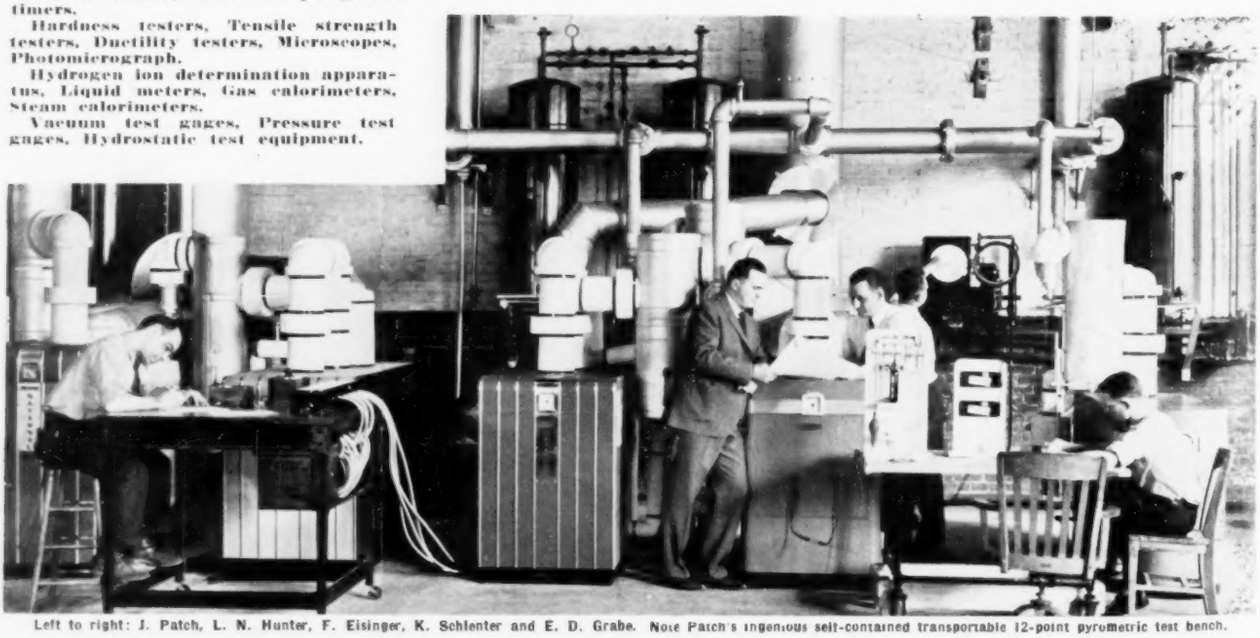
Vacuum test gages, Pressure test gages, Hydrostatic test equipment.

Of all the things we saw that day in Johnstown, the "efficiency test" sticks in our memory as best illustrating the spirit of NRC research. In a highly competitive industry it takes courage for one company to use instruments for finding facts and to publish the quantitative findings. Hunter's men not only follow the ASHVE's recommended methods but they set up with common materials such as are used in ordinary homes (instead of using expensive firebrick and other means of obtaining high readings). Then Hunter releases the data so that all the world may know just what to expect from each size and model. He says that it pays: by attracting top-notch sales engineers and by cementing good relations with manufacturers of burners, stokers and accessories, dealers, consulting engineers and public officials.

In this practical world it is not enough for a company to *deserve* a circle of friends, and we believe that Hunter *wins* them. We base our belief on three facts: (1) he travels widely, (2) he shows numerous visitors through his laboratory, (3) his personality is a winsome combination of youthful enthusiasm and mature judgment, of rural simplicity and urban polish.

Born in 1903 on a farm near Toronto, Hunter took his M.E. in 1925 at the University of Toronto and went to Cleveland where he became half of a heater manufacturing company's two-man research department. Running into chemical problems, he took a post-graduate course in physical chemistry at Western Reserve University—at night and in summer school. He even managed to find time for a course in business administration. In 1930 he was hired by NRC to develop a line of gas boilers. He did this, then he designed special heaters, among them one for treating crude oil—an engineering triumph. Gifted with boundless energy, he not only directs research (the extent of which may be judged by his instrument list) but he collaborates with all other departments at Johnstown—even with art design and advertising—and his duties extend to the company's eight plants from Illinois to Massachusetts.

Backed by President Waters, he urges dealers to use Orsats, draft gages and thermometers when installing and adjusting the heating equipment. The Company's sales policy favors selling each heating plant completely equipped with instruments and controls to assure efficient operation and consumer satisfaction, instead of "stripped" to make the cost seem low. We were happy to learn from Hunter that "everything considered, both we and the customer benefit by this policy."



Left to right: J. Patch, L. N. Hunter, F. Eisinger, K. Schlenter and E. D. Grabe. Note Patch's ingenious self-contained transportable 12-point pyrometric test bench.

THE MONTH'S NEW INSTRUMENTS

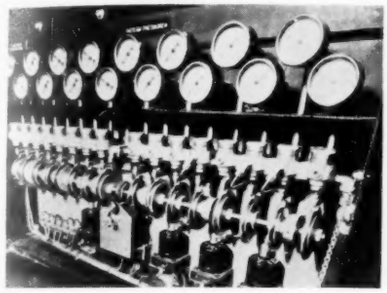
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Complete Process Control

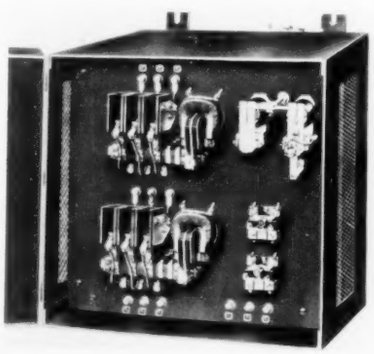
A new system, rather than a new instrument, is announced, combining into one scheduling mechanism and auxiliaries the various automatic-control functions required for an individual processing application. Although designed individually for each processing application, the



"Coördinated Control System" consists of a more or less standard master cam station, and of selected subordinate systems each controlling one factor such as pressure, liquid level, flow, temperature, humidity, etc., by means of an individual valve, damper or other final element. The action of these final elements may be "on-off" or "condition-time-curve" (see *Instruments*, June 1931, pages 336 to 352). Illustration shows a "Coördinated Control System" designed for a solvent recovery plant. Its outside view appeared on the front-cover of the January 1936 issue of *Instruments.—The Bristol Co., Waterbury, Conn.*

Motor Control Devices

Among additions to maker's line of electric motor control devices are several new d-c. and several new a-c. manual and automatic starters, time-limit starters, secondary-resistor and auto-



transformer types for wound-rotor motors, also disconnect switches, manual speed regulators, and miscellaneous accessories such as remote-control stations. Illustration shows "Bulletin 4036" starter, the construction of which is typical of the new a-c. automatics. This starter is non-reversing, primary resistor, current-limit acceleration for three-phase squirrel-cage motors and is available in twenty-five models up to 50 h.p.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

Temperature and Pressure Switches for Boiler Control

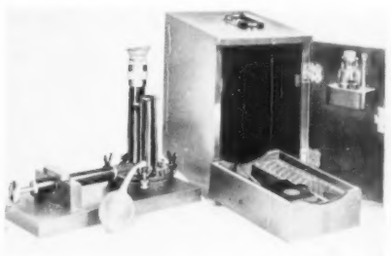
A new line of pressure and temperature controls, the "400 Series," offered to the heating industry for installation as limit switch or operating controls on steam, hot water and vapor systems, or as unit heater controls, is said to embody a number of new features. All units are housed in heavy pressed-steel

cases. All incorporate newly-perfected "Type 780 Magneseal Contact Structure," a completely enclosed, dust-proof and tamper-proof snap-acting permanent-magnet type of contact structure, the use of which in the "400 Series" boiler controls eliminates all internal wiring and pigtails. "De Luxe Model" pressure, vapor and temperature controls are equipped with both adjustable range and differential, adjustments being made outside the case, and with calibrated scale showing the setting of both range and differential. Illustration shows "De Luxe" pressure switch. "Standard Models" have outside range adjustment but with a fixed differential, and are supplied without the outside calibrated scale. New controls are available for limit switch use (close low, open high) or for unit heater applications and water circulator applications to close high, open low. They are rated to include ½ h.p., 110-220 volt a.c., and for 10 amps. 110-volt a.c., non-inductive, or 5 amps. 220-volt a.c., non-inductive service.—*Penn Electric Switch Co., Des Moines, Iowa.*

Dust Counter

With the collaboration of an insurance company, the Bausch & Lomb Optical Co. has developed a dust counter permitting dust counts to be made easily

and accurately without laboratory training or experience by the operator, and is offering it to industry through the Willson safety service organization. This instrument combines in one unit the necessary air sampling device and dark field microscope viewing and counting system, mounted on a circular base, provided with illuminating apparatus and suitably cased for transportation or storage. *Operation:* Air is drawn through a moistening chamber by means of an accurately calibrated hand pump of 0.001 ft.^{3} capacity. The dust particles suspended in the air are impinged on a circular glass plate within the instrument. The dust deposit is in the form of a ribbon. Twelve samples may be collected on one slide. These samples may be viewed and counted at once without removal and they may be preserved for future reference by simply sealing a cover glass to the slide. The



viewing and counting apparatus consists of a built-in compound microscope of 200× magnification with a special dark field illuminating system. The special hyperplane eyepiece contains a micrometer disk ruled in 30-micron squares. An extra line, ruled next to the squares, permits approximate measurement of particles for classification as to size. The apparatus is so calibrated that when multiplying by 100,000 the number of dust particles in the square field the total dust count per cubic foot is secured.—*Willson Products, Inc., Reading, Pa.*

BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

Coin-operated Time Switch

A new coin-operated time switch, "Type TSC-6," for dispensing the service of appliances, operates for 30 minutes when a 10-cent coin is deposited in it.

It is powered by a standard Telechron motor, operating on 25-, 50-, or 60-cycle 115-volt supply. A feature is the off-on device which permits operator to obtain either continuous or intermittent use of the appliance for the full length of time purchased. When entire purchased time has been used, the switch automatically cuts off power to appliance and is ready for another sale. An optional feature is a thermal-cutout device for protection against overload.—*General Electric Co., Schenectady, N. Y.*

Electron Microscope Tube

A newly developed electron microscope tube, referred to as "Type 889," is designed to demonstrate the principles of the electron lens and how they can be used to function as a microscope. The surface of the oxide-coated nickel cathode is enlarged approximately twenty-five times and projected on a fluorescent screen at the end of the tube. Necessary voltage to operate Type 889 may be obtained by a simple power supply. Specifications: Diam. of screen, 2"; Overall length of bulb, 6¾"; Base, 7-prong; Screen, green; Type of cathode, indirect heater; Filament volts 1.5 a-c. or d-c.; Filament amperes, 1.5; Focus electrode volts, 0 to —300 High-voltage electrode, 500 to 1000.—*Allen B. DuMont Laboratories, Inc., Upper Montclair, N. J.*

Surface Temperatures

Flat Stationary or Moving Curved Surfaces

The "Ainor" Combination Pyrocon

Ideal for rolls, molds, plates, platens and plastic material temperatures.

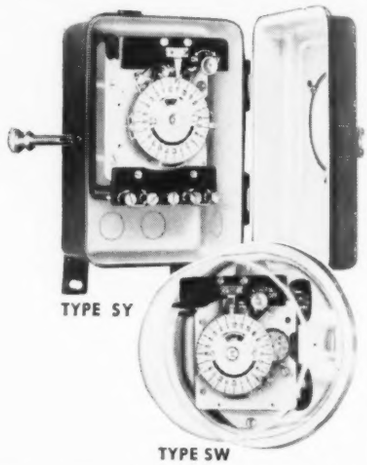
Write for bulletin.

Illinois Testing Laboratories, Inc.

142 W. Austin Ave. Chicago, Illinois

Time Switches

Two new synchronous motor time switches are offered in 4-amp. or 30-amp. capacity for 110- or 220-volt circuits. Each will control almost any type of a-c. circuit operated on a predetermined time basis. Some features: Gears are accurately cut; hardened steel pinions are used throughout; clock plates are heavy to assure substantial bearings; plain or astronomic dials; vernier time adjustments make it possible to set switches within one-half minute. The Sauter SY model with all-metal housing has a broad field of application;



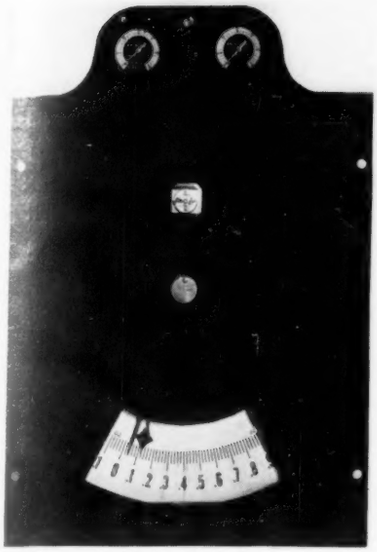
TYPE SW

Model SW, designed for mounting in a standard meter socket, is mainly for off-peak water heating and two-rate metering control although it is equally well suited for almost any type of installation where the all-metal type of housing is used.—*R. W. Cramer Company, 67 Irving Place, New York City.*

pH Meter

New "Hellige pH-Meter" is a unit comprising a rugged glass electrode system, a vacuum-tube galvanometer as the null indicator and "a potentiometer that

gives the reading of the test solution which can be easily lined-up with the potentiometer shaft so that direct readings are obtained regardless of the electrode system used." Compensation for room or bath temperature is made by adjusting the working current of the potentiometer to a temperature scale on the indicating instrument that reads from 10 to 40° C. The new instrument can be used as a vacuum-tube galvanometer if desired. Sensitivity is 0.02 pH, accuracy 0.05 pH.—*Hellige, Inc., 5702 Northern Blvd., Long Island City, N. Y.*



Draft or Overfire Pressure Control System

An air-operated automatic control system for maintaining either draft or furnace pressure at a predetermined value is announced. It consists of instrument (illustrated) and a special damper-operating pneumatic cylinder. Instrument is essentially an inverted-bell type of pressure or draft-responsive element equipped with an "Air-o-line" control system (see *Instruments*, Sept. 1935, page 245), possessing automatic-reset and throttling-range adjustment characteristics whereby predetermined value may be maintained under widely varying load conditions, in large or small boilers. Damper-operating cylinder is equipped with combination pilot valve and piston positioner giving positive response to commands of instrument.—*Brown Instrument Co., 4482 Wayne Ave., Philadelphia, Pa.*

Wide-range Oscillator

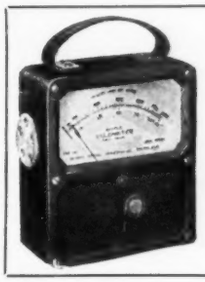
Known as the "All Wave Signal Generator" because its fundamental frequency range extends from 94 kc. to 26 mc., this new instrument is said to be distinguished by the employment of heavy aluminum castings throughout to insure proper shielding and make a low output level possible. In addition, a single rotary selector switch provides modulated, unmodulated, externally modulated r-f, and 4000-cycle audio output, all controlled through attenuator from practically zero to a level sufficient for servicing requirements. Each of the six frequency bands is individually calibrated at six points with quartz-crystal oscillators and it is said that over long periods of time the maximum deviations from original calibration will be <1%. Ladder attenuation system permits using half of knob rotation for first 10% of max. volume and vernier control at low levels. Output voltage variable from approx. 0.5 microvolt to 0.2 volt. A separate tube modulates carrier at 400 cycles. Two units announced: "Model 210" a-c. operated and "Model 211" battery-operated. Dimensions 12½" × 9½" × 6".—*Simpson Electric Co., 5216 W. Kinzie St., Chicago, Ill.*

Metal-clad Joints

Interchangeable ground-glass joints, precious-metal-clad to prevent mechanical and chemical freezing, have been developed. Silver, gold, platinum or palladium are used in sheathing the joints, forming a smooth, non-locking, vacuum-tight seal. Patents have been applied for. Any piece of Pyrex glass apparatus now equipped with interchangeable ground-glass joints may be purchased with metal-clad joints at a slight extra cost.—*Scientific Glass Apparatus Company, Bloomfield, N. J.*

Rectifier for Chargers

New "F-60 Unitron Charger Bulb," designed for use in service-station battery chargers, is a gaseous rectifier tube described as follows by vendor: "Inside the bulb is a filament of coiled wire called the cathode, and a graphite plate, called the anode, and the bulb is filled with argon gas. The filament is heated by current from a special winding on the charger transformer, and the combination of the hot filament and argon gas produces the valve action, in that the positive half cycle is allowed to flow from the graphite plate to the filament, charging the battery, while the negative half cycle is suppressed and prevented from flowing. Therefore, under normal conditions only direct current flows through the circuit." It is stated also that "each bulb is thoroughly tested through a process that duplicates actual service conditions." New tube is guaranteed for "1200 burning hours."—*Allen Electric & Equipment Co., Kalamazoo, Mich.*



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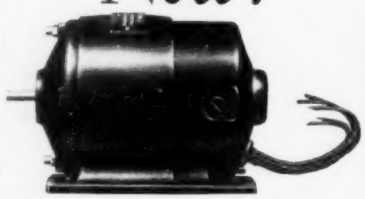


AUTOSYN
SELF-SYNCHRONIZING
MOTOR
TYPE I

Type I Autosyn motor is a reasonably priced self-synchronizing motor with superior performance characteristics. One transmitter may operate as many as six receivers. Practically any system of remote indication or control may be solved by the selection of the proper type of Autosyn Motors.

FEATURES

1. Conventional Motor mounting interchangeable with most standard self-synchronizing motor elements.
2. Approximate accuracy: Two degrees.
3. Maximum torque 14.8 inch ounces.
4. Safe continuous operating torque 5.6 inch ounces.
5. Brushes carry no current during synchronism.
6. Enclosed inertia dampener reduces oscillation to maximum of 3 seconds and is adjustable to suit.
7. Dimensions: 3 5/8"x39/16"x 5 3/4".
8. Weight: 5 lbs., 12 oz.
9. Low current consumption and temperature rise characteristics.
10. Voltage range for accurate and safe operation, minus 20% to plus 10% normal rating.

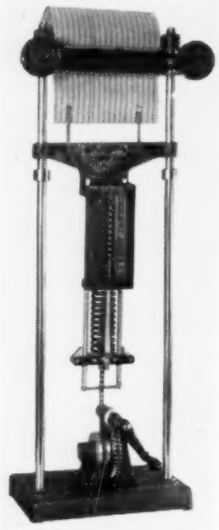
COMPLETE INFORMATION ON REQUEST

BENDIX MARINE PRODUCTS CO., Inc.

Subsidiary of
Bendix Aviation Corporation
754 Lexington Avenue
Brooklyn, N. Y.

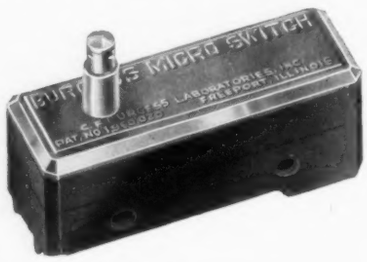
Shopping Bag Tester

This instrument is designed to indicate, in pounds, the force required to pull the handles out of a shopping bag. The usefulness of a shopping bag depends on the effectiveness of the fastening of the handles, which usually are the first parts to give way. The Thwing Shopping Bag Tester was developed to show how much load actually can be applied to the bag before the handles pull out. In order to make the test on the middle portion, the shopping bag is folded at both sides and clamped in the wide jaw; the bag handles are placed around a specially designed clamp which duplicates closely the effect of a hand grip, and the handle at the bottom of the tester is rotated, thereby applying a constantly increasing load—which is indicated on a scale calibrated in pounds. When rupture takes place the pointer automatically stops. The tester has a high gear ratio so that, for practical purposes, it is unaffected by variations in the speed with which the operator revolves the handle. The instrument is portable and can be used by salesmen for demonstrations. It is 31" high, 10 5/8" wide; and weighs <30 lbs. Its capacity is 300 lbs. and it can be used for other purposes by the addition of the necessary holding grips.—*Thwing-Albert Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.*



New Actuating Auxiliaries for Micro Switch

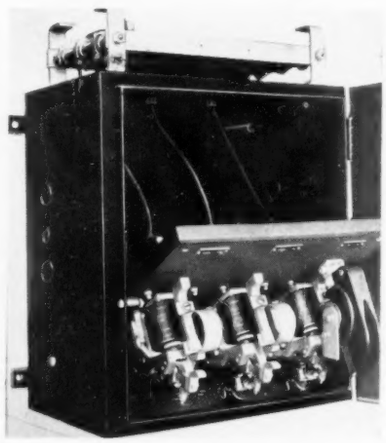
For applications where >1,000,000 operations were required of the Micro Switch (see *Instruments*, July 1933, page 149) it has been necessary to limit the



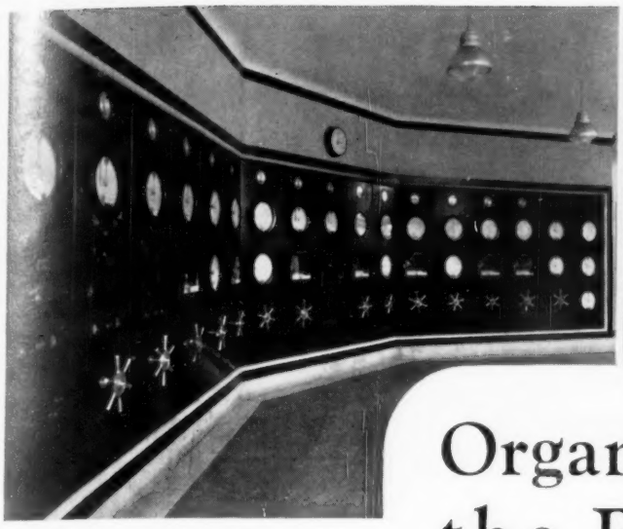
overtravel to 0.005" beyond the operating point. Recent improvements in the internal structure of this switch now automatically limit the overtravel so that a life of >1,000,000 operations may be secured, though plunger goes to extreme limit of travel on every stroke. To facilitate application of Micro Switch to certain types of operations, two new methods of actuation are now available. Either method may be incorporated in the standard normally closed, normally open, or double-throw switch, of either the self-returning or maintaining type. (1) The first actuating device (illustrated) is a sleeve which fits over the standard operating plunger and actuates the switch through a spring in the cap. This spring provides an overtravel of 1/16" beyond the point of operation. When equipped with this spring mechanism, the Micro Switch can be used as a precision limit switch on machine tools that do not stop instantaneously. (2) The other is a leaf spring operating lever, which permits a greater movement of the actuating force than is provided by the standard plunger. By reason of the relatively long lever arm, the operating force required is minimized. Suitable applications are package counting, etc. Use of this spring actuator obviates need for precise location of switch. Spring can be given any shape or length desired to fit special applications.

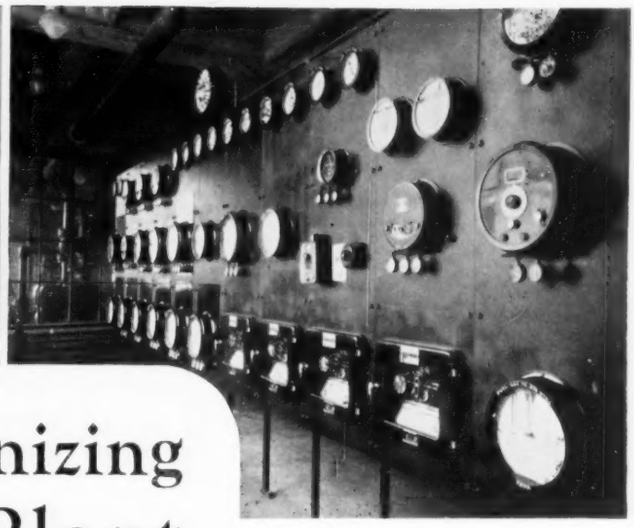
Mill Type Starter

"Type RD" D-C. mill type starter is a standardized unit suitable for use with a wide range of motor sizes and requiring only reconnection of the self-contained resistors to give proper resistor values. It employs the new EC&M "Type RD" mercury acceleration relays



which permit a time range of 1/2 sec. to 2 sec. per step, adjustable by means of a thumbscrew and lock nut arrangement changing the amount of mercury through which the rubber disk must operate. Max. time is secured when disk is at bottom and has to operate through full volume of mercury. A 3-coil unbreakable resistor mounted on top of the cabinet is covered by a ventilated enclosure. By changing the manner in which the resistors are connected, these starters can be used with any motor within the range of 5 to 25 h-p., 230 volts, also on other h-p. sizes on 115- and 550-volt motors within the ampere rating of the contactor. Starter panel is designed, as illustrated, to swing forward to permit access to the wiring at rear. Optional features such as overload relays, main line knife switch, field acceleration relay, etc., can be incorporated where required.—*The Electric Controller & Mfg. Co., 2700 East 79th St., Cleveland, Ohio.*





Organizing the Plant Instrument Services

By ALFRED G. MOON

Increasing use of instruments, and recent progress in automatic control technique, require organization changes in each of the process industries. The Plant Instrument Department (under various names) grows in importance, but some high executives still feel that a special organization is unnecessary and that almost anyone can select, install and service modern instruments and control systems. For years we have known that a large oil company has not only a million-dollar instrument installation but a well-organized and splendidly manned Instrumentation Service; and we have wished to print a description of it. This progressive company does not wish its name used, but has granted Mr. Moon permission to write a series of two articles *in general terms* for the benefit of our readers: (1) organization and (2) training. Here is the first article. Please note that it is not a specific description but a generalized discussion.—Editor.

IN 1906 we stood on a curb and amusedly watched strange-looking horseless carriages go by jerkily and noisily. Today we get behind the wheel of the descendant of these machines, and glide along smoothly, silently and swiftly. This growth and development is paralleled by that of the oil industry. Years ago oil was fractionated in relatively small quantities, in horizontal batch stills, arranged to be used singly or in cascade. Today we process 20,000 bbls. (50s), or more, in 24 hours in one unit.

With the old equipment, if any operating instruments were used at all, they consisted of indicating thermometers and pressure gages. The first recorder installed aroused much curiosity. The modern unit is operated from a central location, where the operators have under their observation and for their manipulation: anticipatory controllers for regulation of pressures, temperatures, liquid levels and flows; recorders for such operating information as is needed but not directly controlled; indicators to supplement or check the recorders; devices for the remote control of valves; etc.

The tendency is toward more accurate control of component parts of the complete cycle, necessitated by increasing throughputs and by operation closer to critical temperatures. So close is this control maintained that a difference of 10° in a 1,000°F. range spells the difference between large output and complete stoppage of production. In addition to the fractionation and cracking operations, the treating and refining of lubricating cuts are undergoing radical changes, requiring the latest in control and recording instruments.

Just as the operating equipment has changed in the past few years, so the modern controller dates its advent from about 1931. The development of the anticipatory type of controller opened a new field of control, but it did more: it changed the type of men needed as instrument men.

Thanks to modern control systems, the process development engineer can design the operations to much closer limits, with assurance of having the test-tube results reasonably reproduced in plant equipment. The use of these automatic systems permits large-scale chemical processes to be handled with a minimum operating force and with a degree of uniformity of output not possible with older types of commercially-available instruments. We place emphasis on this because of the radical change caused in instrument servicing and maintenance, and we shall develop this theme as we proceed.

Some organizations have been installing modern control equipment without adequate provision for proper installation and maintenance, the inevitable consequence being failure to obtain expected results — whereupon the instruments are condemned. With the increasing refinement and complication of instruments, the need for adequate supervision and trained mechanics becomes more imperative, if the capital investment in instrumentation is to yield the return anticipated. As a matter of interest to executives charged with the instrumentation policies of their organizations, we describe a typical instrument organization applicable to a large oil refining or chemical plant.

Before considering what is needed in the matter of organization, let us first examine what a group such as we have in mind would be called upon to do. The instrument group would be charged with the selection as to type and make, based on required service, correct installation, and proper maintenance. Some instruments would be installed individually, such as distribution meters measuring steam, gas, air or water, required by various departments or operations; others would be grouped together on panels in control rooms for the information and guidance of the operators. In one control room we may encounter instruments from five or six

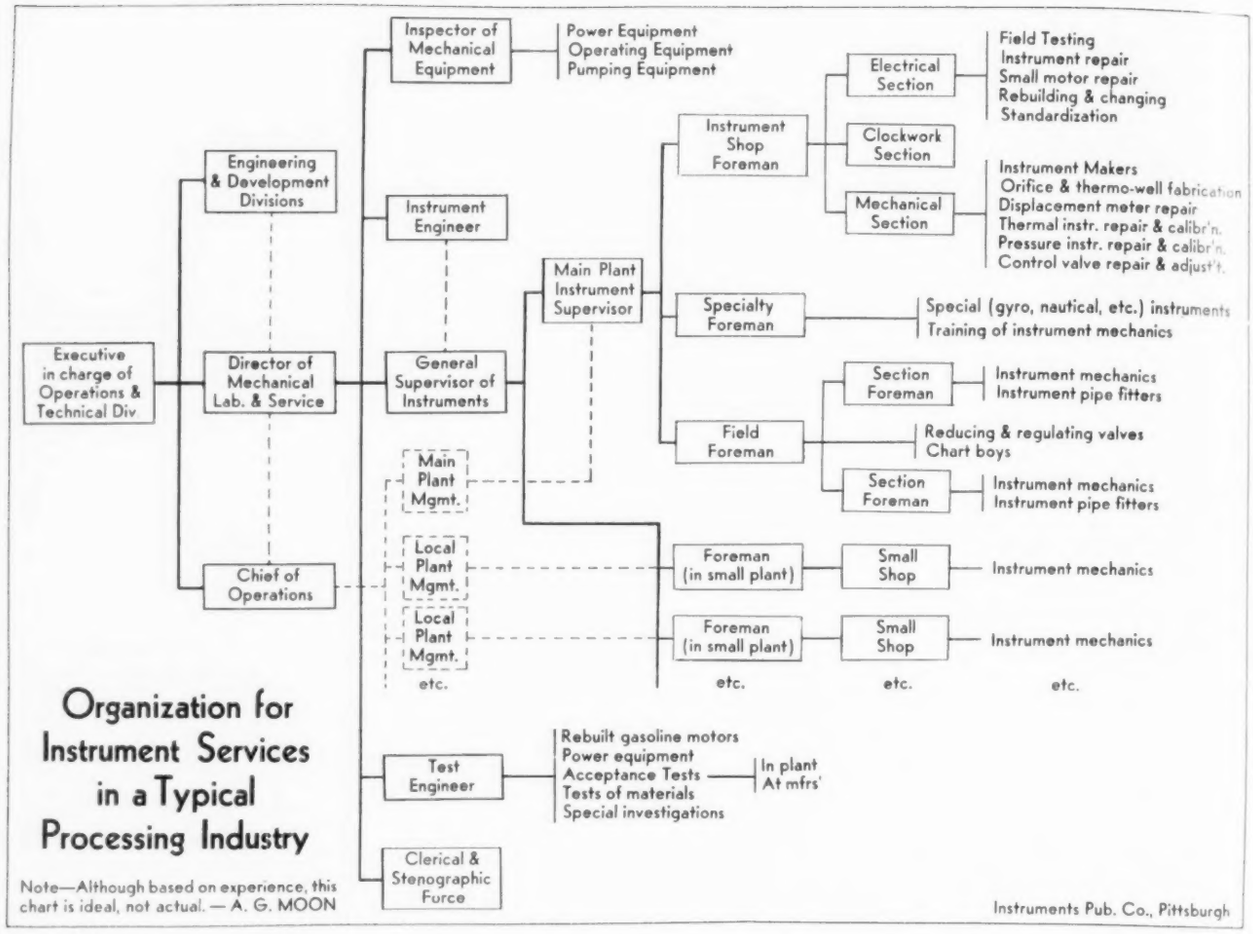


Fig. 1

manufacturers, and four or five types of any one vendor's products.

A glance at the accompanying photographs of typical control rooms [at the head of this article] shows a wide variety of instruments, including vacuum indicators, pressure indicators, pressure recorders, pressure recorder-controllers; flow indicators, flow recorders, indicating and recording flow controllers; liquid level controllers; temperature indicators, temperature recorders, temperature recorder-controllers, both electrical and mechanical, and remote controls for valve operation. Looking around outside at the operating equipment, we would see pressure gages, float-operated liquid level indicators and controllers, vacuum recorders, as well as round-edge orifices limiting flow.

Behind the successful functioning of these instruments we find an organization set-up somewhat on the general lines shown in Fig. 1. This general form of organization has been found, after fifteen years' experience, to lend itself well to installing and maintaining approximately 2,000 recorders and controllers and 5,000 indicating instruments, representing the products of forty manufacturers. (Of course, it is obvious that such a set-up would be out of place in a small plant, or in any plant having comparatively few instruments.)

For organizations having a number of plants, the General Supervision and Headquarters Functions, hereinafter described, could be profitably centralized at the home office. It is hard to generalize, but experience indicates that a fairly typical plant, with twenty to thirty recorders and controllers in addition to simple indicating instruments, can profitably utilize the full-time services of at least one first-class instrument man.

The set-up shown in the chart is more nearly ideal than the usual existing instrument groups. Many organizations with a number of sizable plants maintain separate instrument groups at individual locations without specific general supervision. Thus they lose the advantage of uniform practice, purchase and servicing. Another factor favoring centralization is that industrial instrumentation, particularly in the chemical industries, has changed so radically in the past six or seven years that it is beyond the hit-and-miss stage and is fast becoming the function of highly specialized engineers. The organization is shown reporting directly to one of the executive staff to assure impartial inspection, testing and instrumentation for the various company units.

The functions shown on the chart may be described as follows:

The Director of the Mechanical Laboratory and Services should be charged with the selection of personnel and general direction of the functions outlined in the chart. Along with this should go coöperation with the Research, Engineering, Operating and Purchasing Divisions in selection of power consuming and heat transfer equipment as well as instruments.

The functions of the Test Engineer and of the Inspector of Mechanical Equipment may be found on the chart. We need not describe them in detail here.

The Instrument Engineer should take care of instrument records, orifice design, idle instrument lists, etc. A record should be kept of every instrument, which may

be accomplished by using an envelope system as shown in Fig. 2. The record should be started by noting the pertinent facts on the face of the envelope, while inside should be filed (1) a copy of the requisition and (2) subsequent reports and calibrations as turned in on a simple form provided for that purpose (Fig. 3).

All records should be kept according to serial numbers, a cumulative history of the instrument thereby resulting. Accurate lists of idle instruments should be maintained, in order to supply, when possible, instruments requested by the operators or engineers.

An important function of the Instrument Engineer is the design of orifice plates for flow measurements, which constitute a goodly proportion of the instrument installations in a chemical plant. The orifices used in connection with all new installations, as well as replacements or changes, should be calculated and ordered from the instrument shop as required. It is ofttimes necessary to replace an orifice in a hurry by reason of changes in operating requirements. Our own organization has designed, fabricated and sent to the field in an hour, orifices for measuring gas in terms of normal temperature and pressure at unit gravity when flowing at other conditions. In a small group, at least one man should be familiar with orifice design, as fabrication of plates and the preparation of correction factor, flow conversion curves and planimeter tables will result in substantial savings in the course of a year. Naturally, the greater the number of installations, the greater the savings. These curves and tables are, of course, of great importance when a bonus is paid for the economical use of steam, air and gas, where pressure and temperature compensating elements are not included in the flow measurements. A word of caution is necessary at this point. While there is nothing mysterious about orifice design, there are enough pitfalls present to lead the unwary into serious errors, and results should be checked against a primary standard before accepting maiden efforts as being within one percent correct.

The Instrument Engineer also calculates, from field calibration reports, the correction factors to be applied to reading of meters involved in measurements of fluids and gases, on which bonus payments are based. These correction factors are then transmitted to the company Division interested.

The clerical and stenographic force has the usual functions and need not include technically-trained personnel unless it numbers more than five or six, in which case a male technically-trained chief clerk is of value.

Reference to the diagram shows the next major division to be the field force. Under this heading come the various plant instrument foremen who have under their direction field organizations adequate for the service required. The size of the local organization may vary from one man to the number required to fill the functions outlined for the main or large plant.

We purposely speak first of the field mechanics because their importance is overlooked in too many industries. They are divided into sections to conform to the geographical divisions of the company. Each section should be complete for the type of work required. The field mechanics should make routine inspections, routine repair and maintenance, install new instruments, change existing installations, equalize and calibrate units on regular schedule or as requested. Each instrument man should be assigned definite duties at the start of the day's work. Some to make regular inspections and take care of such instruments as may be found to need attention, others to calibrate such instruments as are scheduled for that day or overhaul and repair items needing to be worked on. This work includes any type or make of instrument used in the plant, as the mechanics should be trained to handle them all. It is necessary for a top-flight man to know the details of the operations on which the various controllers are used, as it frequently is found that a controller is in proper working order but is prevented from functioning by reason of an upset somewhere else in the system. The field should be equipped with such test facilities as are needed to check the operating instruments; standardization should be done in the shop and not in the field. The care of steam reducing and regulating valves is a function of the field force. Changing charts is properly a function of the instrument group as many an instrument can be thrown off by rough handling. Proper installation is as important as correct selection. No instrument can give reliable results if it is installed without regard to detail of connections, mounting and future servicing. Pipe work is usually in small sizes, and experienced pipe

Fig. 2

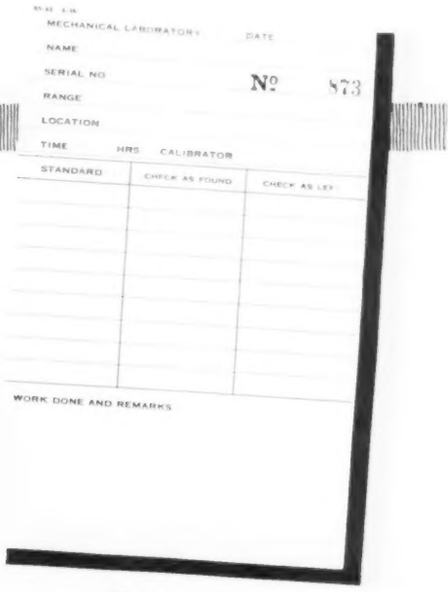


Fig. 3

gangs save expense and foremen's time by being able to proceed with installations, line clearing, orifice changing, freeze-up work, thermo-well inspection, etc., with a minimum of personal guidance. An inexperienced gang requires a foreman or instrument man every minute, and takes longer than a smaller group of well-trained men. The qualifications of a well-trained instrument mechanic will be discussed in a later paragraph.

Detailed description of servicing and trouble-shooting cannot be undertaken in this article, nor can the important subject of installation be covered. Such items as the why of suppressed zero on liquid-level instruments having materials of different gravity in the two leads, capacity of sealing chambers, material of orifice plates, piping up flow instruments, etc., constitute a whole science—enough to fill a 300-page handbook.

The instrument shop should be equipped with precision tools to make major repairs, calibrate and standardize instruments, fabricate parts, and even fabricate whole instruments with speed and precision, because emergencies arise where a stock of "spares" is not the answer.

The instrument shop foreman has under his direction the following:

(1) The Electrical Section:

This Section overhauls, repairs, rebuilds or changes the ranges of electrical instruments. It has charge of the "primary" and "secondary" electrical standards. The "primary" standards are those instruments which have been calibrated at the National Bureau of Standards; the "secondary" standards are similar instruments which have been checked against the first group and form the working standards. This section takes care of all major repairs which are not reasonably field work; however, when certain field checks are required involving the use of shop instruments or standards, the electrical specialists are sent out. The men used in this group should be graduate electrical engineers because the tendency is toward greater variety and complexity of electrical control instruments.

(2) The "Clock Maker":

In a large plant with several thousand mechanical and electrical timepieces used in recorders, integrators and controllers, it is a matter of economy to employ a professional repair man rather than attempt to train one. This man should also repair mechanical counters, azimuth circles from ship equipment, etc.

(3) The Mechanical Section, which includes:

(a) A pressure instrument division, where the indicating and recording pressure or vacuum gages are repaired and are calibrated by a man especially trained for this work.

(b) A temperature instrument division, where indicating and recording thermometers are checked and repaired. For a large plant this section is capable of making major repairs, refilling the tube-systems, changing ranges without impairing accuracy, and expeditiously building special recorders. Trained instrument men are used here.

(c) Thermo-wells, thermocouples, orifice plates and miscellaneous parts are fabricated as ordered. A high-grade lathe hand is employed for this work.

(d) Displacement meters are overhauled and calibrated by an all-round instrument shop man.

(e) An important section is one in which special instruments are built to order for the research laboratory and other laboratories, and special small equipment fabricated for other divisions. This work is done by skilled machinists who are experienced as tool and model makers and who therefore can work with the precision and ingenuity required.

(f) The repair and setting of air-motor-operated control valves is taken care of in the shop.

(g) Coöperation with the Plant Stores department is maintained by checking all of the instrument parts and equipment ordered for stock, to make certain that the material is as required; all pressure gages and glass stem thermometers are checked before being put in stock for issue.

The third section of the field force should be under a foreman who is responsible for repair and maintenance of highly specialized instruments (such as gyro equipment and other instruments of a fleet of ocean-going ships plus auxiliary craft). The foreman of this section may be charged also with the direct supervision of the instrument apprentices.

Previous to the fundamental change in mechanical controller design mentioned above, the average instrument man could be recruited from the ranks of the skilled trades. This was particularly true when the types and makes of existing instruments were not too varied. Now, however, the picture has changed, and while the skilled trades may still supply some potential material, we require applicants with more than manual dexterity. They must give evidence of analytical ability, and possess a type of personality which will get along well with the operating force.

The instrument mechanics are divided into various classifications, according to their ability to meet the specification for the rating. We give below the specification for First-class Instrument Mechanics.

Educational Requirements: High-school education, supplemented by two or more years of evening technical school.

Experience Necessary: At least five years' including, preferably, a specific apprenticeship course on instruments. The applicant must be able to service and maintain *all* of the various types of instruments and control devices put on the market by at least *five* manufacturers out of a list of *eight*: eight names out of the following twelve firms whose instruments we use in large numbers:

Bailey	Foxboro	Republic-Smoot
Bristol	Leeds & Northrup	Simplex
Brown	Mason-Neilan	Tagliabue
Cochrane	Precision	Taylor

The eight names on the list used in our Personnel Department represent the eight makes in most numerous use by us; the other four makes are not represented in quite sufficient numbers here to be included in our outside-experience qualification. Twenty-eight other makes of instruments are used in small numbers, the total of makes being forty.

Requirement for the Rate: In addition to the foregoing qualifications for education and experience, an applicant for this rate must be familiar in general with plant operations and have considerable detailed knowledge of the more important processes on which the instruments are used.

The above requirements narrow the sources of supply to three:

1. Men who were formerly service men for one of the "complete-line" industrial instrument companies.

This source is open to the objection that the applicants usually only know one make thoroughly, be it electrical or mechanical—seldom both, and therefore must be hired as third- or fourth-grade mechanics and be given considerable training. Experience indicates that it takes two or three years before they merit the first-class rate.

2. Instrument mechanics formerly in other industries.

These were sometimes hired, but it has been found that experienced all-around men are not plentiful; the floaters who offer themselves are usually not worth the expense of putting them on the payroll. Occasionally a top-notcher can be found who for some good personal reason desires to make a change. The writer's experience in obtaining properly qualified instrument men indicates that out of every hundred applications probably twelve to fifteen will be worth interviewing, with a resulting selection narrowing down to two or three prospects.

3. Graduates of the Company's own training school for instrument men. A comprehensive training program, starting from scratch with carefully selected candidates, appears to be the road to obtaining the help needed to service the modern instruments. Such a plan is, of course, out of the question for the small individual plant; but where a number of small or large plants are under one organization it may be of interest to know how one such program is worked. We shall, in the subsequent article, describe in detail a three-year training program for instrument mechanics now in actual use.

Photoelectric Photometers and Colorimeters

By KASSON S. GIBSON
Chief, Colorimetry Section, National Bureau of Standards

3. PHOTOELECTRIC DEVICES FOR QUANTITATIVE CHEMICAL ANALYSES.

Of the numerous forms of so-called "colorimeters" employing photoelectric cells, we may first consider those used for quantitative chemical analysis. These are really instruments of the type discussed in Sections 1 and 2 and, in fact, are not always called colorimeters. Where the designation "colorimeter" is used, it has doubtless been applied from similarity to or association with colorimeters of the Duboscq type, which, however, do not measure color or color stimuli, nor yield a color specification, but merely use a color match or nearest color match as a criterion for the quantitative determination of the concentration of a solution in terms of a calibrated standard. Such instruments might better be called, simply, comparators; or, where filters are used and a photometric measurement made, they might be called filter photometers. Scientific descriptions of instruments of this type, with discussion of sources of error and their elimination, have been published[14]. They are sensitive and, while not affording the complete analysis given by the spectrophotometer, are useful in chemical and biochemical analysis when used intelligently and with adequate knowledge of the various factors involved.

4. PHOTOELECTRIC DEVICES ADVERTISED FOR GENERAL COLORIMETRIC USE.

We come now to the field of "general colorimetry" and to the ever-growing group of photoelectric devices being placed on the market under trade names implying that they are general-purpose colorimeters. While the instruments themselves are of numerous different sizes and shapes, and employ various principles and various types of light-sensitive elements, it will be found that they are similar in nearly all respects to the instruments discussed in Sections 1, 2 and 3. In fact, if all such photoelectric instruments on the market were exhibited in one room, the ones discussed above along the north wall and the ones now to be discussed along the south wall, it would be impossible—even after examining and testing all the instruments—to see why there should be on the south wall a bold sign reading "Colorimeters" or some such label implying wider fields of application than the ones for which the instruments on the north wall are suitable. The major difference seems to be in the statements which are appearing in the advertising literature. These are often false or seriously misleading. It is reasonable to suppose that each instrument was designed by an engineer or physicist, and that then, in many cases, a hasty advertising writer prepared the literature as he would a "campaign" for a cheap paint. Such statements as " * * * is an electro-optical instrument for making any and all colorimetric and turbidimetric measurements" or "indicates the existing discrepancy to the millionth degree" or "provides a color check heretofore impossible" may be mere instances of advertising license permitted by usage in the general field of advertising, but the designers and manufacturers would do well to strike them out of their advertising men's copy because the intelligent instrument buyer—even if he has not learned the science of colorimetry—will gain a bad impression of products so advertised.

Equally unfortunate are specific statements which the designers and manufacturers no doubt did not get a chance to see before they were printed. For example the statement "not subject to . . . color blindness" implies that the instrument fails to take advantage of a most useful property of photoelectric cells, namely, that they are all totally color-blind. And the statement "Note that * * * can 'see' ultraviolet and infra-red rays" describes what would be a serious defect for colorimetric purposes if true.

The question may then properly be asked, to what extent and under what conditions can these instruments give reliable colorimetric data? The answer is two-fold:

(1) From any one reading or determination, with or without a filter, no value can be obtained which may properly be called colorimetric, unless previous calibration of the instrument combined with knowledge of the material being tested makes it possible for such a reading to be safely interpreted in colorimetric terms.

(2) If readings are made through three filters properly chosen with respect to the accompanying photocell and illuminant, these readings may serve to give trichromatic coefficients such that two samples which gave identical readings would be of the same color when compared visually and such that any differences in readings could be correlated with differences in the colors of the samples. However, the usual red, green, and blue filters will not adequately serve for this purpose, nor will any three which are mutually exclusive with respect to the spectral region transmitted.

Here again, as was the case with the visibility data discussed above, it is found that data representing the chromatic vision of normal observers differ considerably and it is, therefore, necessary in this case also to select data representative of an average normal observer and duplicate this by means of filters as accurately as possible. Such an observer was established in 1931 at the meeting of the International Commission on Illumination and is known as the 1931 I. C. I. standard observer[15]. Data defining a standard trilinear coördinate system, incorporating the standard visibility data, were also adopted as well as standard illuminants A, B, and C, representative of incandescent light (gas-filled, tungsten-filament lamps), noon sunlight, and average daylight, respectively[2].

An understanding of the principles underlying 3-filter photoelectric colorimetry can perhaps best be obtained by treating the subject under the following headings: (1) Derivation and use of the ideal filters for obtaining values exactly on the 1931 I.C.I. basis, (2) approximation to these ideal filters obtainable in actual filters,

[14] See for example:
A. H. Sanford, C. Sheard & A. E. Osterberg. The Photelometer and Its Use in the Clinical Laboratory. *American Journal of Clinical Pathology*, Vol. 3, 1933, pages 405-420.
J. H. Yoe & T. B. Crumpler. A Photoelectric Colorimeter. *Industrial & Engineering Chemistry, Analytical Edition*, Vol. 7, 1935, pages 281-284.
A. Goudsmit, Jr. & W. H. Summerson. A Variable-layer Photoelectric Comparison Photometer. *Journal of Biological Chemistry*, Vol. 3, 1935, pages 421-433.

[15] The standard data are based on measurements by Guild and Wright on 17 normal observers. See Guild. The Colorimetric Properties of the Spectrum, *Philosophical Transactions of the Royal Society*, Vol. 230, Series A, 1931, pages 149-187.

and (3) the nature of the errors involved in 3-filter photoelectric colorimetry.

(1) Derivation and Use of the Ideal Filters for Obtaining Values Exactly on the 1931 I.C.I. Basis.

Let X, Y, and Z be the distribution coefficients defining the 1931 I.C.I. standard observer according to the 1931 I.C.I. coördinate system, these being a function of wave-length and referring to an equal-energy spectrum (see Fig. 4). The ideal filters for use with a photoelectric cell, by means of which colorimetric data may be accurately obtained for this 1931 I.C.I. standard observer and coördinate system, are given by the following equations:

$$T_x = \frac{k_x XE'}{sE} \qquad T_y = \frac{k_y YE'}{sE} \qquad T_z = \frac{k_z ZE'}{sE}$$

where X, Y, and Z are the spectral distribution coefficients just noted, E is the spectral energy of the illuminant used with the filters and cell in the measurements, E' is the spectral energy of average daylight or other illuminant by which the samples are ordinarily viewed, s is the spectral response of the photocell to an equal-energy stimulus, k_x, k_y, k_z are constants, and T_x, T_y, T_z are the desired spectral transmissions of the three respective filters. If with such filters the instrument scale readings be designated as a_t with the test sample in position and a_o with the standard of reflectance (or transmission) in position, the ratios of such readings through the three filters in turn are designated as

$$\bar{x}' = \left(\frac{a_t}{a_o}\right)_{x\text{ filter}} \qquad \bar{y}' = \left(\frac{a_t}{a_o}\right)_{y\text{ filter}} \qquad \bar{z}' = \left(\frac{a_t}{a_o}\right)_{z\text{ filter}}$$

The quantities, $\bar{x}'$, $\bar{y}'$, and $\bar{z}'$ may in themselves serve as a colorimetric specification of the sample relative to the reference standard. In order, however, to express the specification in terms of the 1931 I.C.I. standard observer and coördinate system, the I.C.I. colorimetric values of the reference standard must be known. Let x_o, $\bar{y}_o$, and $\bar{z}_o$ be the tristimulus values of the reference standard (for illuminant E') on the 1931 I.C.I. standard basis. (See references 2, 4, and 13 for definition of "tristimulus value" and for methods of computing such values from spectrophotometric data.) An adequate colorimetric specification of the reference standard is afforded by the values $\bar{x}_o$, $\bar{y}_o$, and $\bar{z}_o$. In this connection it may be noted that the value of $\bar{y}_o$ is equal to the luminous reflectance (or transmission) of the reference standard for illuminant E'.

A second method of expressing the colorimetric values of the reference standard is by way of the trilinear coördinates (also called trichromatic coefficients), combined with the value of y_o. The trilinear coördinates of the reference standard are defined as

$$x_o = \frac{\bar{x}_o}{\bar{x}_o + \bar{y}_o + \bar{z}_o}$$

$$y_o = \frac{\bar{y}_o}{\bar{x}_o + \bar{y}_o + \bar{z}_o}$$

$$z_o = \frac{\bar{z}_o}{\bar{x}_o + \bar{y}_o + \bar{z}_o}$$

The chromaticity of a color is indicated by the trilinear coördinates, and since the sum of these quantities is always unity, any two of them may serve to specify chromaticity. The color of the reference standard for illuminant E' may, therefore, also be adequately specified in terms of x_o, y_o, and $\bar{y}_o$.

It is desired to express the tristimulus values, $\bar{x}$, $\bar{y}$, and $\bar{z}$, or the trilinear coördinates, x, y, z, of the test

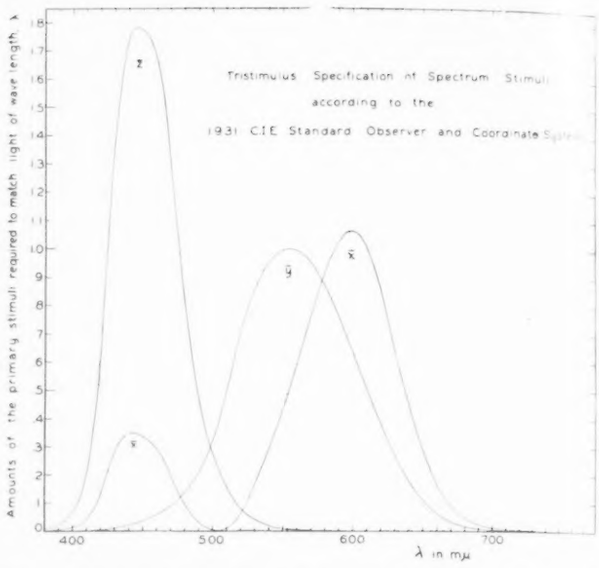


Fig. 4. Spectral distribution coefficients (designated as X, Y, and Z in the article) defining the 1931 I.C.I. (French C.I.E.) standard observer according to the 1931 I.C.I. co-ordinate system.

This illustration and Fig. 5 are from the paper by Judd (ref. 2) which should be consulted for full explanation.

sample in terms of the measured quantities, $\bar{x}'$, $\bar{y}'$, $\bar{z}'$, and either $\bar{x}_o$, $\bar{y}_o$, $\bar{z}_o$ or x_o, y_o, z_o pertaining to the reference standard. This is done by means of the following relations:

$$\bar{x} = \bar{x}'\,\bar{x}_o \qquad \bar{y} = \bar{y}'\,\bar{y}_o \qquad \bar{z} = \bar{z}'\,\bar{z}_o$$

$$x = \frac{\bar{x}'\,x_o}{\bar{x}'x_o + \bar{y}'y_o + \bar{z}'z_o}$$

$$y = \frac{\bar{y}'\,y_o}{\bar{x}'x_o + \bar{y}'y_o + \bar{z}'z_o}$$

$$z = \frac{\bar{z}'\,z_o}{\bar{x}'x_o + \bar{y}'y_o + \bar{z}'z_o}$$

The color of the test sample for illuminant E' may, thereupon, be expressed in terms of the 1931 I.C.I. standard observer and coördinate system by giving values of $\bar{x}$, $\bar{y}$, and $\bar{z}$ or x, y, and $\bar{y}$. It may be noted that if the reference standard is non-selective with respect to wave-length (*i.e.*, constant throughout the visible spectrum) the values of x_o, y_o, and z_o become equal to the respective similar quantities for the illuminant E'. The usual diagram for plotting x and y is illustrated in Fig. 5.

(2) Approximation to the Ideal Filters Obtainable in Actual Filters

In attempting to duplicate the ideal values of T_x, T_y, and T_z defined above, it will be found that the problem is greatly simplified if the X distribution function is treated as if the parts above and below 505mμ were separate functions[12]. Furthermore, below 505mμ the X function has relative values very similar to those of the Z function. For practical purposes, therefore, it is necessary to duplicate T_x only at wave-lengths greater than 505mμ, the transmission of the filter being zero below this wave-length. Such a filter may be designated as an (x) filter, with spectral transmission values $T_{(x)}$. In this case, the value of $\bar{x}'$ may be taken as equal to

$$0.83\left(\frac{a_t}{a_o}\right)_{(x)\text{ filter}} + 0.17\left(\frac{a_t}{a_o}\right)_{z\text{ filter}}$$

the values, 0.83 and 0.17, being proportional to the areas

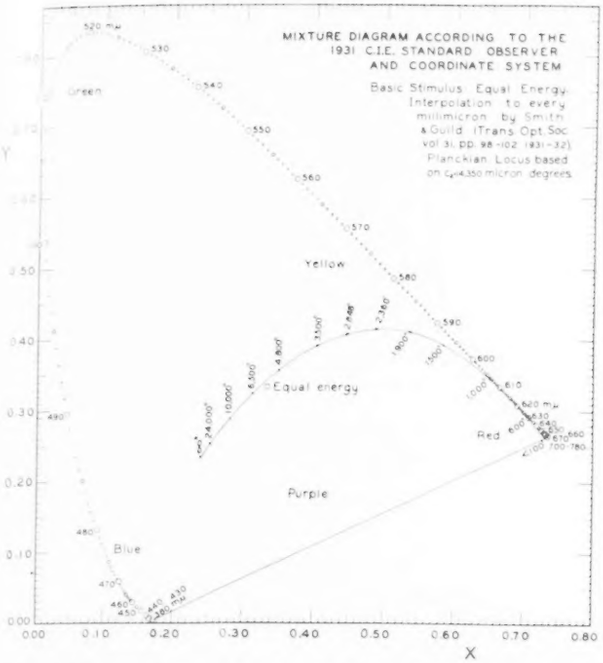


Fig. 5. Mixture diagram showing the locus of the spectrum and the Planckian radiator in terms of the trichromatic coefficients x and y. For further explanation, the paper by Judd (ref. 2) should be consulted.

of the X curve above and below 505mμ. Values of $\bar{y}'$, and $\bar{z}'$ are obtained and computations of $\bar{x}$, $\bar{y}$, z, and x, y, z made as described in the previous sub-section.

Values of T_x, $T_{(x)}$, T_y, and T_z have been computed for values of s representative of Weston Photronic, Westinghouse Photox, and General Electric Hewlett cells, and with values of I.C.I. illuminant C taken for E' and I.C.I. illuminant A for E. These values are available upon request to the colorimetry section of the National Bureau of Standards. They are, of course, valid only to the extent that the values of s assumed in the several cases apply to any particular cell. They show clearly, however, that yellow, green[16] and blue filters, rather than red, green, and blue filters, are necessary to duplicate $T_{(x)}$, T_y and T_z, respectively. As a further guide to the proper kind of filters, it may be noted that a first, though crude, approximation to the desired values of $T_{(x)}$, T_y and T_z is afforded, in the case of Photronic and Hewlett cells, by filters composed of the following glasses: (1) dark railroad signal yellow plus pale sextant green for $T_{(x)}$, (2) pale sextant green for T_y and (3) very dark signal blue plus Noviol A for T_z. These combinations effectively exclude the ultraviolet and infra-red regions.

In case it is not desired to obtain data on the I.C.I. basis but merely to obtain adequate colorimetric data for accurate matching or control purposes, the filters just suggested, or any others which will give curves more closely approximating the ideal $T_{(x)}$, T_y, and T_z curves, should be satisfactory for most purposes. In such use of the filters one need not compute the x' value, as was done above by weighting the values of a_1/a_0 obtained through the (x) and the z filters, but can use values of $(x)'$, y', and $\bar{z}'$, directly. In this case, further, if magnesium oxide is used as the reference standard, one may consider that

$$(\bar{x})_0 = \bar{y}_0 = \bar{z}_0 = 1.00$$

and

$$(x)_0 = y_0 = z_0 = 1/3$$

and that the effective illuminant E' (which will probably approximate daylight) will have the same values. The values of the trilinear coördinates (x), y, and z will, therefore, be simply

$$(x) = \frac{(\bar{x})'}{(\bar{x})' + \bar{y}' + \bar{z}'}$$

$$y = \frac{\bar{y}'}{(\bar{x})' + \bar{y}' + \bar{z}'}$$

$$z = \frac{\bar{z}'}{(\bar{x})' + \bar{y}' + \bar{z}'}$$

(3) The Nature of the Errors Involved in 3-filter Photoelectric Colorimetry

When colorimetry is attempted with a photoelectric cell and a set of three filters such as described above, the nature of the errors which may be present will depend, of course, on whether or not one is attempting to obtain data on the 1931 I.C.I. basis. If one desires to get values of x, y, and $\bar{y}$ on this standard basis, of as high accuracy as are obtainable with good spectrophotometric data and computations, he will probably be disappointed except in the measurement of small differences where values for the standard are independently known. The method may prove of considerable accuracy for white or near-white materials, although actual test will be necessary in any case to determine the exact magnitude of the errors involved.

If one is not attempting to obtain data on the I.C.I. basis, the only criterion for accuracy is the consistency obtained with the results of visual grading or examination. Reproducibility will prove nothing if the filters are of the wrong type. It should be emphasized that the reliability of such method over a period of time is dependent on the constancy and reproducibility of the various parts contributing to the colorimetric values obtained.

The method outlined above for using a photoelectric 3-filter instrument for colorimetric purposes, whereby values of $\bar{x}$, $\bar{y}$, and $\bar{z}$ or x, y, and $\bar{y}$, or similar quantities, are obtained suitable for specification of the color, is probably the best general procedure for such work. In many cases these values are sufficient in themselves. In others, it is found that still greater usefulness is obtainable for certain purposes by using combinations of these quantities as the important variables, such as x/y or $(\bar{x}-\bar{z})/\bar{y}$, which may be found satisfactory for representing differences in yellowness, or red-green differences, etc. This depends on the particular problem. Other schemes are possible such as successive subtraction of the least of the quantities, $\bar{x}$, $\bar{y}$, $\bar{z}$, then the least of the residuals, etc., but it is doubtful that such systems are as useful as the more direct methods of specification.

5. MISCELLANEOUS FACTORS AFFECTING RELIABILITY OF DATA OBTAINABLE WITH THE INSTRUMENTS DISCUSSED ABOVE

In the previous sections consideration has been given almost entirely to the spectral characteristics of the various parts of the instrument contributing to the determination of the various colorimetric data. In addition, however, there are several other factors that must be considered in any careful study of the reliability of the various instruments. These may be considered under four headings:

[16] The green filter is unnecessary with a Photox cell. The sensitivity of this cell is so low in the blue, however, that it is not recommended for 3-filter colorimetry. On the other hand, its spectral response curve approximates the visibility curve better than do the response curves of the other cells noted; for this reason it is somewhat more suitable than they for the measurement of luminous values (see Section 1, above) when no correcting filter is used with the cell.

1. Mechanical Stability

The instrument should be of sufficiently rigid construction that ordinary accidental pressure on any part will not affect the readings. The sample holder should be of such design and construction that the samples can always be placed precisely in a definite reproducible position.

2. Thermal Stability

The operating characteristics of the cells may be affected by change of temperature, likewise the spectral transmissions of the selective filters. Certain filters, such as those made of selenium glass, are so sensitive to temperature change that they should not be used. The construction of the instrument should be such that the heat from the illuminant upon both the cells and the filters, either by radiation or convection, is minimized.

3. Electrical Characteristics

Three factors are to be considered:

(1) Stability of the response. Certain cells are somewhat unstable; different readings may be obtained depending on whether the cell has just previously been exposed to strong or to weak irradiation.

(2) The electric circuit used. The important question is, if the incident radiant energy is increased or decreased by any definite amount, its spectral distribution being unchanged, will the instrument reading be increased or decreased in precisely the same proportion? Under certain conditions departure from proportionality may be serious. The makers of the cells give considerable information on these points and their descriptive circulars should be consulted. Circuits and cells which have proved satisfactory are described in a number of references, some of which are listed below[17-20].

(3) The permanence of the response characteristics of the cells. Some cells deteriorate so that their response to a given illumination may be appreciably lower at the end of a year than it was at the beginning. If an indicator is calibrated to register a definite value for a given illumination, it is particularly important to know that the cell being used is stable in its response. In instruments where the cell response for unknown samples is compared periodically with its response for known standard samples, or where ratios only are determined, this deterioration factor is automatically compensated.

4. Optical Characteristics

The optical design of an instrument will, of course, depend on the purpose for which it is designed. This purpose may be the measurement of absorption, reflectance, opacity, turbidity, or color. In some instances adequate diagrams showing the optical and mechanical details are apparently not available, nor are scientific descriptions of the instruments. It is, therefore, impossible to judge properly the design of these instruments. In view of the great variety in design and purpose of the different instruments, the writer cannot do more than indicate a few points of importance in any consideration of such instruments.

In any measurement of absorption, it is important that the light pass through the solution or other sample approximately at right angles to the end surfaces of the material. Otherwise the values obtained apply to greater than the measured thicknesses. It is furthermore important in accurate work to insure that the multiple reflections between the samples and the optical parts of the instrument do not introduce error in the results. For example, if one attempts to measure the transmission of a non-diffusing, non-absorbing glass plate by inserting it in the beam directly in front of a dry-disk type of cell, about 8% of the light reflected from the cell is reflected back to the cell from the plate and makes the value of transmission obtained too high. The error may in many cases be computed but it is best to eliminate it entirely if possible. If the transmission of diffusing materials is being measured, the angular conditions of illumination and observation are also of importance, as in the case of reflectance measurements.

Several factors are of importance in measuring the apparent reflectance of materials relative to a reference standard, which is the sort of measurement for which many of these instruments are designed. These will be enumerated in turn.

1. The angular conditions of illumination and observation

These should be explicitly and accurately stated, if results obtained by one design of instrument are to be compared with similar results by another design. Not only are the angles of incidence and reflection of importance but also the angular apertures of the beams. However, the importance of these factors in affecting the readings depends notably on the diffusing properties of the material being studied. They are of great importance in the case of a material such as aluminum paint, whose apparent reflectance may vary from less than 0.25 to more than 1.00 depending upon these conditions of measurement. They are of relatively little importance in the case of matt surfaces such as certain paints, papers, etc. The most suitable conditions to use depend on the material to be measured and the purpose of the measurements. Conditions which have been commonly used are (1) diffuse illumination and normal viewing, which, if the illumination is completely diffused, gives values of apparent reflectance equal to the reflectance for unidirectional normal illumination, and (2) 45° unidirectional illumination and normal viewing, conditions recommended by the International Commission on Illumination, and the equivalent condition of normal illumination and 45° viewing.

2. The reference standard of reflectance

Formerly magnesium carbonate has been widely used. However, the reflectance of this material is apparently much more variable than is that of magnesium oxide which is gradually superseding the former for this purpose. Information regarding the preparation and colorimetric properties of a magnesium-oxide reflectance standard is published in *National Bureau of Standards Letter Circular LC-395.*

3. Equality of illumination on sample and standard

Any failure in this respect will, of course, produce error. Lack of equality may be caused by (a) poor optical or mechanical construction, and (b) difference in illumination of sample and standard caused by their own differences in reflectance, this possibility occurring in instruments using illuminating spheres, hemispheres or other inclosures, where both sample and standard are not simultaneously illuminated[21], and in the use of cover glasses over sample and standard[22].

[17] L. A. Wood. A Differential Circuit for Blocking-layer Photo-cells. *Review of Scientific Instruments,* Vol. 5, 1934, pages 295-299.

[18] L. A. Wood. Zero-potential Circuit for Blocking-layer Photo-cells. *Review of Scientific Instruments,* Vol. 7, 1936, page 157.

[19] Ch. Zinzadze. Photoelectric Photometers for Use in Colorimetry. *Industrial & Engineering Chemistry (Analytical Edition),* Vol. 7, 1935, pages 280-281.

[20] Anon. Instruments for Use with Photoelectric Cells. *Electrical Measurements,* Vol. 1, No. 4, July, 1935. Published by Sensitive Research Instrument Corporation, 4545 Bronx Blvd., New York City.

[21] A. C. Hardy and A. W. Pineo, The Errors Due to the Finite Size of Holes and Samples in Integrating Spheres. *Journal of the Optical Society of America,* Vol. 2, 1931, pages 502-506.

[22] D. B. Judd and K. S. Gibson, Note on the Effect of a Cover Glass in Reflectance Measurements. *Journal of Research of the National Bureau of Standards,* Vol. 16, 1936, pages 261-264; also *National Bureau of Standards Research Paper* No. 872 issued separately as a pamphlet.

Testing Friction Tapes and Rubber Tapes

By W. H. S. YOURY

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FRICTION and rubber tapes are used widely in the installation of new plant, in maintenance, and in repair work. Friction tape is relatively strong cotton tape impregnated with an adhesive rubber compound that makes successive layers stick firmly together when wrapped around any object. Rubber tape, or splicing compound, as it is commonly called, is a ribbon of soft unvulcanized or partly vulcanized rubber, which also sticks to itself tenaciously and becomes a solid mass of insulation as successive layers are wrapped.

Commercial types of tape differ greatly in their characteristics. Friction tapes vary from the so-called wet variety — which are sticky or tacky—to the dry tapes, which have a relatively non-tacky surface. Rubber tapes vary from the soft, almost unvulcanized compounds, which are tacky and of low tensile strength, to the more vulcanized types of considerable tensile strength, which are not tacky. The most desirable type of tape depends upon the use to which it is to be put, and to insure the best possible tapes for the Bell System, conditions of use are studied as a basis for specifications.

The important service requirements of friction tape for the Bell System are that the material must be strong enough not to tear when it is being wrapped tightly onto any object, and that it shall stay in place indefinitely after application. It is essential also that the tape surfaces have the qualities of adhesiveness and tackiness which make the material relatively easy to unroll and apply whether it is freshly made or a year or so old.

Easy application qualities are particularly convenient when the friction tape is used to provide temporary protection for an unsheathed cable core that has to be left overnight. Fig. 1 shows how the tape is applied by moving the roll so that while kept on edge, it is rolled around the cable core in a spiral path. It shows also the fingers of one hand picking the edges of the tape wrapping to check whether or not the tape adheres well to itself. Rubber tape, being extensively used to wrap joints in wire used outdoors, needs to have handling qualities which facilitate application as a relatively smooth built-in-place rubber insulation free from unclosed passages through which water might enter. The stretchable character of rubber tape enables it to be wound on an irregularly-shaped joint without leaving cracks under the edges of the tape. This need for tightly sealed rubber tape wrappings is an important reason for the disfavor of "combination" tapes in outside plant use.

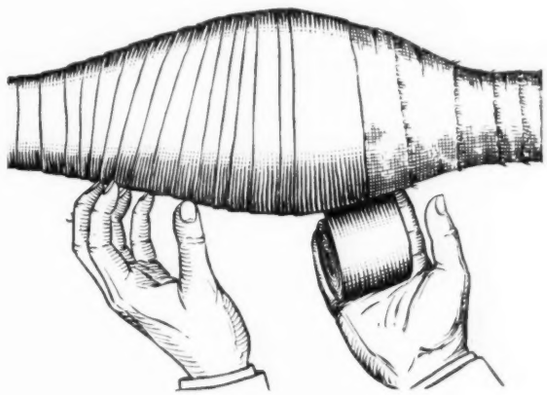

Fig. 1. Method of wrapping friction tape on a splice.

Fig. 2. Making an adhesion test of friction tape.

Certain specification requirements are framed primarily to control the handling qualities of both friction and rubber tapes. These requirements cover such properties as tensile strength, elongation, and tackiness.

Other requirements, intended chiefly as criteria of the serviceability in the telephone plant, are those limiting adhesion: the force required to pull the tape surfaces apart after they have been pressed together about as tightly as they would be in practical use. Tests for tackiness and adhesion are made on both kinds of tape as purchased and also after an accelerated aging treatment.

The adhesion of friction tape is determined by the use of the apparatus shown in Fig. 2. A strip of tape is wound on a mandrel under a specified tension, produced by a weight hung from the end of the strip. After the tape is fully wound up, it is held under winding pressure for a specified time, and then the winding weight is replaced by a lighter one, giving a load of 4 lbs. per inch of width, and the roll is allowed to unwind under its action. The distance it unwinds in one minute is a measure of the adhesion.

This comparatively simple method of measuring adhesion is not entirely satisfactory for rubber tape, because when layers of rubber tape are pressed together, the surfaces in contact practically fuse together, and the force required to pull them apart is affected by the stretching of the tapes as their surfaces are separated. The apparatus and method developed in the Laboratories

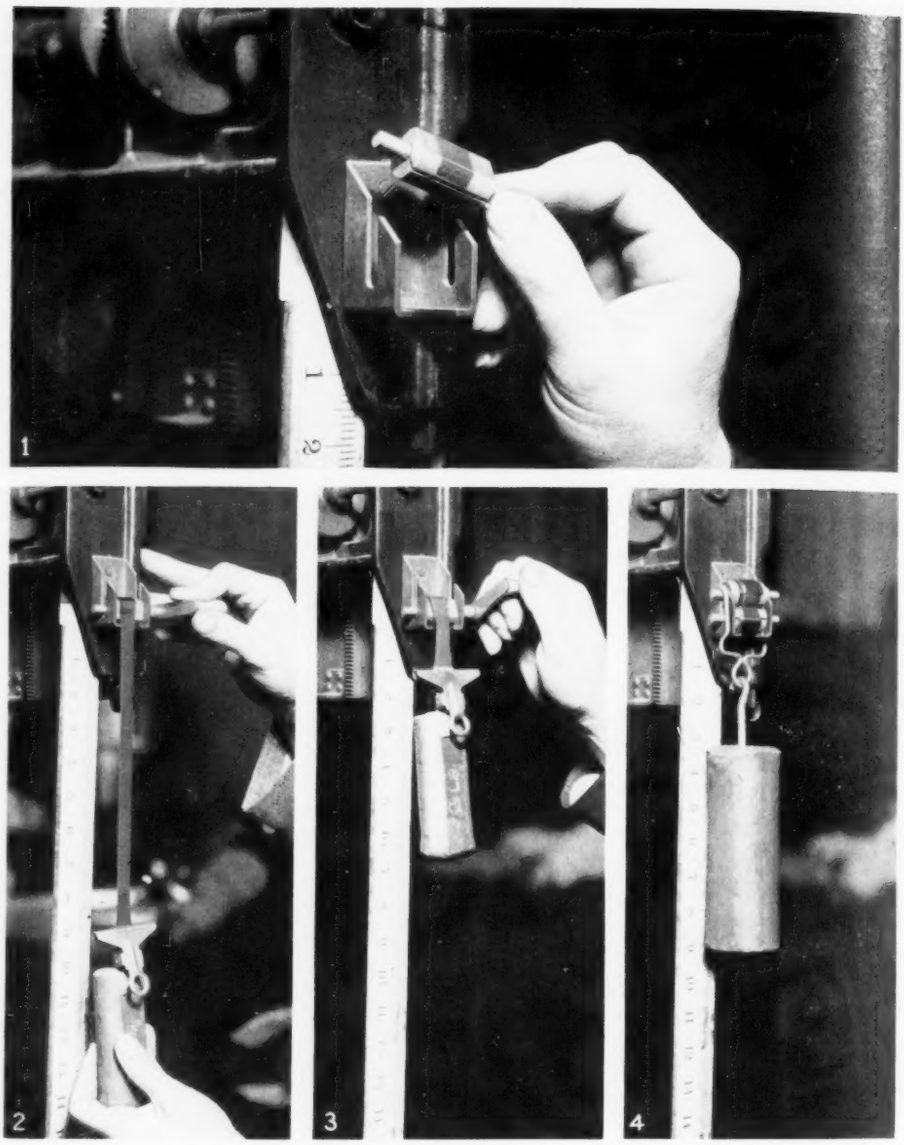

Fig. 3. (1) One of the two mandrels used for adhesion test of rubber tape; (2) tape is first stretched to three times its original length; (3) it is then wound on the mandrel under a prescribed load; (4) two of the mandrels so wound are then pressed together at a specified pressure and for a specified time.

to minimize the variations in testing the adhesion of rubber tape are shown in Fig. 3. Each of two small cylindrical mandrels cut flat on one side is first wound with four layers of the tape stretched to three times its original length and wound on under the tension of a definite weight. Then the two flattened sides are pressed together under a specified load and for a specified time. Following this they are removed to a tensile testing machine, and the force required to pull them apart is taken as a measure of their fusion.

Tests for tackiness need not be so definitely quantitative. A rough evaluation of the tackiness of friction tape is obtained by holding the two ends of a strip a few feet long, and then flipping the surfaces of the tape into contact. After this light contact they should stick together with appreciable force, which is judged by the effort required to pull them apart. One surface of the tape usually differs from the other in tackiness, and the test is made for the three possible side-to-side combinations. Tackiness of rubber tape is evaluated by stretching it to three times its length, winding it under tension on a mandrel and noting if there is a tendency for the winding to unroll when the tension is released.

It is just as important for tapes to have satisfactory characteristics a considerable time after manufacture as it is to have them good when new. For this reason the Bell System requires that tapes meet a set of requirements after a specified aging procedure. In general, the aging of tapes is greatly accelerated by high temperature, exposure to sunlight, or contact with air with an appreciable ozone content. Many types of aging tests have been employed by the Laboratories in their studies of tapes. The test employed for inspection purposes, however, consists in storing the rolls of tape for four days in a temperature of 70°C. Studies have shown that tapes having satisfactory properties after this aging procedure will also be satisfactory for plant use after more than a year of ordinary shelf storage.

Most commercial tapes are wrapped in waxed paper, metal foil, or cellophane, which besides making a more attractive package is presumed to give better shelf aging. Experimental work in the Laboratories, however, has not substantiated this belief, and consequently no such wrapping is required for the Bell System: each roll is packed in a cardboard container and no other wrapping is required. Both rubber and friction tape are supplied in three widths, $\frac{3}{4}$", 1", and 2". Friction tape is supplied also in four colors. Black is the one most commonly used, but gray, ivory, and dark brown are available where color matching is desirable. Since the rubber tape is almost invariably covered with friction tape, color is of little importance and is not specified. It is usually gray or black. Two sizes of rolls are used for friction tape—36 and 75 feet respectively. The smaller roll is particularly useful where space is at a premium, such as in wrapping aerial cable where the roll must be passed between the cable and the messenger. Rubber tape is not supplied in rolls of more than thirty feet, since larger rolls would be too bulky.

It would require from fifty to one hundred fully loaded five-ton trucks to carry the friction and rubber tape used annually by the Bell System. The quantity purchased in any one year, if in $\frac{3}{4}$" width, would make from five to ten strips across the entire breadth of the United States from New York to San Francisco.

Cathode-ray Oscillograph Applications

Fifteenth part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in the July 1935 issue.

By RALPH R. BATCHER

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WAVE-FORM ANALYSIS WITH A SINUSOIDAL TIME BASE[22-25]

This method may be in reality a modification of either the linear time base method, heretofore described, or the polar method, depending upon the relative frequency of the timing sweep. If it is adjusted for some submultiple of the frequency of the wave under investigation, the trace of those cycles that appear near the center of the screen may be analyzed as linear. If the frequencies are equal, either a curve of the polar type or a "cyclogram" results.

The wave-form of the time base must be essentially a pure sine curve, or the wave-form of the potential under investigation will be distorted. Corrective measures in the form of filter circuits through which the timing wave must pass, may be applied. One such arrangement disclosed by Irwin,[26] Fig. 20, is especially adapted to circuits using magnetic deflection coils *D-D*. In this circuit the deflection coils are tuned to resonance to the incoming frequency using a suitable condenser C_2 in parallel with them. This parallel combination is connected to the supply through a series resonant circuit, RLC_1. Likewise tuned to the supply frequency. With this arrangement the timing deflection is obtained from the source of power under investigation, and so it eliminates all need for an auxiliary oscillator and means for synchronizing it to the system, and therefore represents an extremely simple method of delineating waveform.

[22]Cramp, Cyclograms for Studying Wave-form. *Journal Institute of Electrical Engineers*, Vol. 69, 1930, pages 81-82.
[23]Lubke, Frequenz Elektrische Wellen Wechselstromkurven. *Archiv für Elektrotechnik*, Vol. 6, 1917, pages 161-164.
[24]Chubb, Polar and Circular Oscillograms. *Electric Journal*, Vol. 11, 39, 1932, page 863.
[25]Brown, Analysis of Amplifier Harmonics. *Physical Review*, Vol. 39, 1932, pages 863.
[26]Irwin, Oscillographs. Isaac Pitman's.

It is stated that when L and C_1 are essentially in resonance, small changes in L will produce considerable change in the phase of the currents, a feature that may prove useful in other studies.

Oscillograms obtained with a synchronous sinusoidal time base can be converted to the corresponding type in rectangular coördinates and vice versa by using a graphical construction. A circle is drawn with a diameter equal to the extreme length of the oscillogram projected on the horizontal axis. The circumference is divided into a number of equal sections as in Fig. 21. As shown at the right, an equivalent number of equally-spaced ordinates are erected on the extended horizontal axis, to form the field for the rectangular system. The point of intersection of the oscillogram with each successive radius is then projected to the series of ordinates at the right, where they indicate the contour of curve *B*, Fig. 21.

To indicate the process with a single transportation, the process is also shown in Fig. 22. A line *AB*, perpendicular to the horizontal axis, intersects the circle at the angular distance θ and is extended to the oscillogram at *B*. The line *AB* is projected to the rectangular coördinates on that particular ordinate representing the angular distance θ.

A similar process can be used to plot the harmonic content of the wave only. Along each vertical ordinate at the right the linear distance between the point on the circle and the point on the oscillogram directly above (or below) it will produce the curve *C* in Fig. 21.

The process of converting a polar curve to rectangular coördinates is similar, except that the equally-spaced ordinates of the rectangular diagram are given heights proportional to the radial distances from the origin (the

Fig. 20

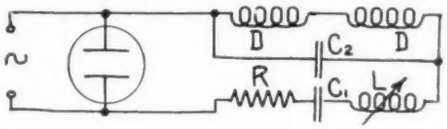


Fig. 22

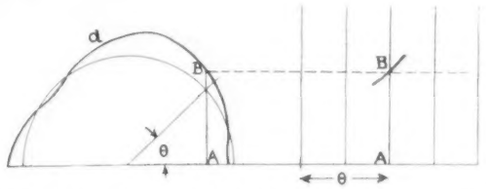
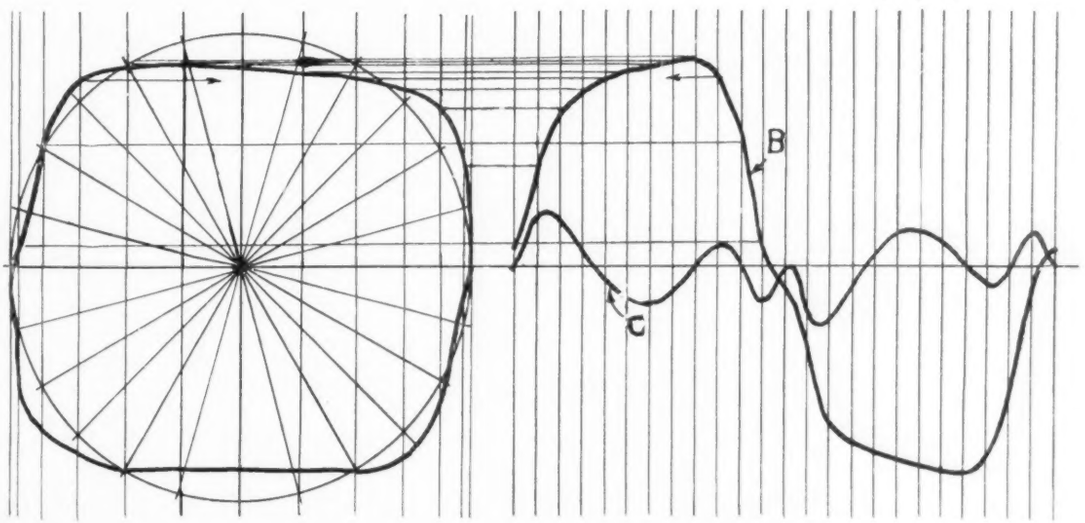


Fig. 21



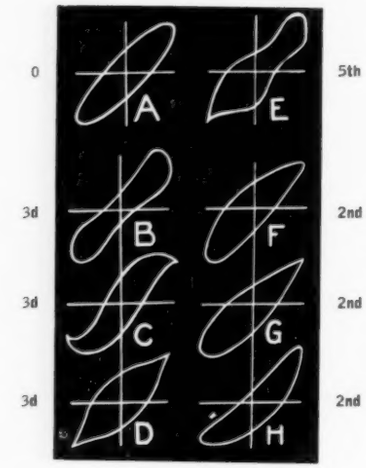


Fig. 23

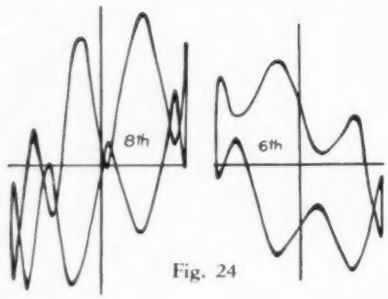


Fig. 24

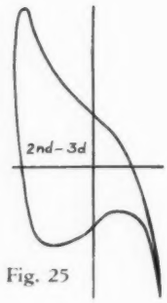


Fig. 25

intersection of the axes) to the curve, the distances being measured along spaced vectors equal in number to the number of ordinates used (not counting the last vertical ordinate which corresponds mathematically to the first one).

The rules applicable in the estimation of harmonics present based on the elliptical form of diagram, are not as definite or as accurate as with the linear type. A number of analytical methods for such cases have been published at various times. The amount of eccentricity with respect to the horizontal axis denotes the relative amount of one or more even harmonics.[27] This eccentricity can be indicated by quickly reversing the connections to the vertical deflection plates, whereby the diagram reappears inverted on itself. Other methods for this analysis make use of special scales, templates, and polar planimeters and so on account of their complexity will not be repeated here.[28, 29, 30]

In Fig. 23A a true ellipse is shown, which is obtained when the wave applied to the vertical plates is without harmonics. The horizontal deflection is produced in each case by the application of a synchronous sinusoidal wave to the horizontal plates. In contrast with this figure the next three diagrams show the effect of a third harmonic, the difference between B, C, and D, Fig. 23, being the phase displacement between the fundamental and harmonics. Fig. 23E shows the effect of the fifth harmonic, and the last three diagrams, F, G and H, show the distortion produced by a second harmonic with various phase differences. The above-mentioned eccentricity can be noted in these diagrams.

[27]Roder. A Simple Method of Harmonic Analysis. *Proceedings Institute of Radio Engineers*, Vol. 19, 1931, pages 1481-1487.

[28]Wood. Phase Measurements with a Cathode-ray Oscillograph. *Review of Scientific Instruments*, Vol. 2, 1931, pages 644-648.

[29]Karapetoff. Mechanical Means for Studying Oscillograms. *Journal American Institute of Electrical Engineers*, Vol. 46, 1927, pages 1457-1458.

[30]Taylor. The Measurement of Radio-frequency Power. *Proceedings Institute of Radio Engineers*, Vol. 24, 1936, pages 1342-1366.

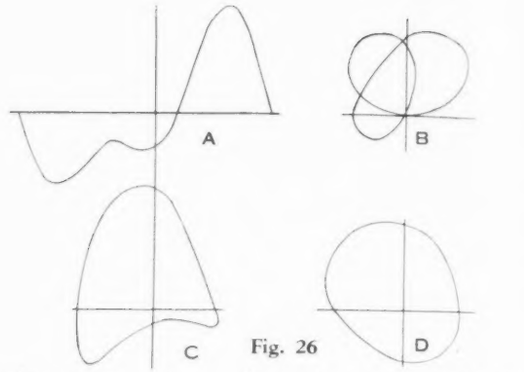


Fig. 26

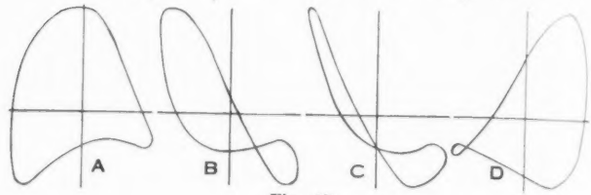


Fig. 27

Fig. 24 shows the same type of diagram with relatively large amounts of the eighth and the sixth harmonics, while Fig. 25 shows a representative diagram when two harmonics are present, in this case the second and the third. When the wide variety of possibilities in the matter of both relative amplitude and phase differences are considered it will be seen that many types are produced by the same two harmonics.

POLAR CURVES

The term "polar" diagram has often been used rather loosely in describing the above type of cathode-ray oscillograms. True polar diagrams cannot be easily produced with a cathode ray tube, with usual means.*

To bring out the distinction a series of possible methods by which a speciman wave-form might be delineated is shown in Fig. 26. The linear curve A is a sinusoidal wave to which a 50% second harmonic with a 15° phase angle has been added. A true polar curve of the same wave is shown at B. If A had been a sine wave without harmonics the polar diagram would have been a circle passing through the origin. In this case however a two-lobed figure results. In B the radius vector rotates at a constant speed, one revolution per cycle, and has a length equal to the instantaneous value of the potential.

Lissajous figures produced by applying the same wave-form to the vertical plates and a sine wave having the same frequency to the horizontal plates will give a diagram as at C. This curve is but one type of figure that might be found, since differences in phase between the wave and the time base will alter the appearance. With other phase relations the appearance of C may differ as shown in Fig. 27, where several other possibilities are shown. No matter what the appearance, if any of these figures are converted to rectangular coördinates by the method of Fig. 21, the same curve will result (that of Fig. 26 curve A) although it may start and stop at a different point in the cycle.

A fourth type of curve might be obtained where the wave A, Fig. 26, produces radial deflections to and from a circular time base. In this case the appearance depends upon the relative amplitude of the superposed deflection. This type of diagram is shown in Fig. 26D.

*One method would be to apply the measured wave to a pair of deflection plates and then to rotate the tube in synchronism around its own axis. Or else to apply the wave to deflection coils that are rotated in synchronism around the tube. A third method is to photograph the diagram with a polar camera such as has been described in the July 1936 article.

Still another curve (not shown) would be obtained if the wave under test could be applied to the deflection plates through a phase-shifting circuit. The actual shape might be similar to Fig. 26C but will vary depending on whether a resistance-capacitor or an inductance-resistance circuit is used.

Referring again to the phase-splitting circuits, it is advance evident that the fundamental and each harmonic will be affected differently by the divided circuit.[22] In the resistor-condenser circuit, the component of the potential across the condenser due to the harmonics are relatively unimportant compared with the same component across the resistor. However, the reverse is true in the case of a resistance-inductance rotator circuit. Again, in the case of a rotator circuit using a virtual resistance, such as Fig. 38, April 1936 article, the resistor *LC* acts as a condenser for all harmonics and so suppresses the deflection produced therefrom. A circular time base produced by a "virtual" resistance-condenser rotator circuit shows less effect of any harmonics that may be present in the applied wave.

CIRCULAR PHOTOGRAPHS

In certain tests involving wave-form studies it may be possible to simplify the analysis by making a circular photograph of the diagram, as explained in the July article, page 199. The basic diagram is a circular figure, where the harmonics produce radial deflections. A photograph of this figure is made on a rotating film, clamped on a disk rotating in the focal plane of a lens, at a speed equal to the frequency of the wave under investigation.

If rotated in the right direction, a circle on the screen will be photographed as a single spot. An ellipse will appear as a small circle whose diameter is equal to the difference between the major and the minor axes. A similar ellipse produced by a wave having a certain amount of the second harmonic will appear as in Fig. 28b. The latter diagram is not unlike the polar curve shown in Fig. 26. Where adjustments of the deflection potentials are made so that a circular time base is obtained, this arrangement in effect eliminates the fundamental from the problem, leaving only the harmonics to be analyzed.

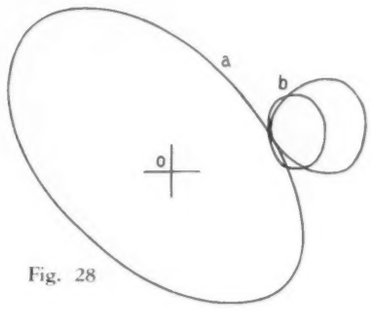


Fig. 28

Physical difficulties inherent with this method in the matters of producing synchronous rotation, of producing a true basic circle, and of keeping the lens and the circle concentric, make this arrangement less useful.

The Lakeside Station's "Model" Control Board

CITY OF SPRINGFIELD, ILLINOIS
DEPARTMENT OF
WATER, LIGHT AND POWER

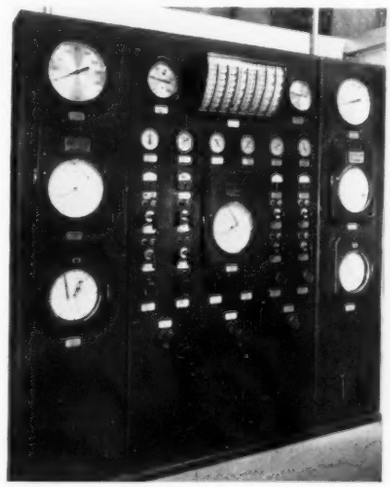
To the Editor of *Instruments*

IN reply to your inquiry we take pleasure in giving you the following brief description of the boiler control board in our new Lakeside Station.

The Lakeside Generating Station, which is used for generating electric energy and pumping water to the city, is part of a project by the City Water, Light & Power Department which includes a new artificial lake of 21 billion gallon capacity and a new water purification plant. The first section of the generating and pumping plant was put into operation last Spring. This section consists of one 110,000 lb./hr. Springfield boiler and one 10,000 kw, 3600 rpm., General Electric turbine operating at 400-lb. 700° steam.

The left panel (as one faces the board) has mounted on it, from top to bottom, a Crosby steam pressure indicator, a Bailey boiler drum water level recorder, and a Taylor three-pen recorder showing the preheated air temperature and the temperature of the flue gases entering and leaving the preheater.

The center panel has a Hays eight-unit pointer draft gage indicating the following pressures, reading from left to right: forced draft, secondary air west burner, secondary air east burner, furnace draft, boiler outlet, induced draft, coal-air west mill, and coal-air east mill. The draft gages are flanked by Taylor tem-



perature indicators, showing the temperature of the two burners. Immediately below the draft gages is a row of six indicators of the Hagan boiler-control system. A Bailey boiler meter, recording the air flow, and recording and integrating the steam flow, occupies the central portion of the board. To the left of the boiler meter are mounted two Westinghouse speed indicators for the forced-draft and for the induced-draft fan, two Westinghouse pistol-grip switches for starting and stopping the motors on the two fans, and two Westinghouse pistol-grip switches controlling the motors on the pumps connected to the hydraulic couplings which connect the driving motors to the fans. To the right of the boiler meter are two Westinghouse ammeters showing the current used by each pulverizer motor, and four Westinghouse pistol-grip switches for starting and stopping each of the pulverizer motors and each of the pulverizer feeder motors. A red and a green light above each switch indicate whether that circuit is closed or open. The nine remaining control knobs on the center panel are part of the Hagan boiler-control system.

The right panel has on it, from top to bottom, a Crosby feed-water pressure indicator, a Bailey feed-water flow recorder and integrator, and a Taylor two-pen temperature recorder showing the temperature of the feed water entering the boiler and of the steam leaving the boiler.

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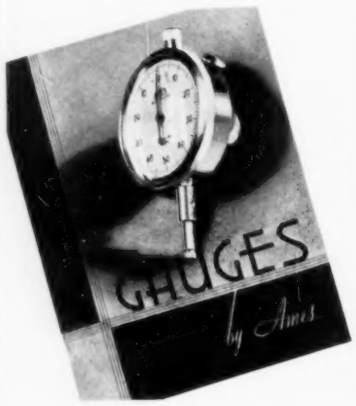

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Oscillography

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By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*

(*Continued*)

5. Recording and Visualizing Means

(a) General Principles

Brief references have been made in previous sections to devices whereby the motion of the responsive element (whatever its type) may be observed or recorded. Such devices are of necessity incorporated in all types of oscillographs, and their forms vary considerably. There are, however, only a few basic principles which need to be utilized, and in the following paragraphs these will be set forth as they are employed in electromagnetic and other moving-*part* oscillographs, *i. e.*, those oscillographs which incorporate "vibrators."

The vibrator of an oscillograph serves the purpose of imposing upon a beam of light movements representative of the changes in the current under investigation; but in order to make use of this vibrating beam or pencil, there must be provided means by which the *ordinates* traced out by the vibrator may be combined with suitable *abscissae*—generally in terms of time. The light beam is derived from a concentrated source, either an arc

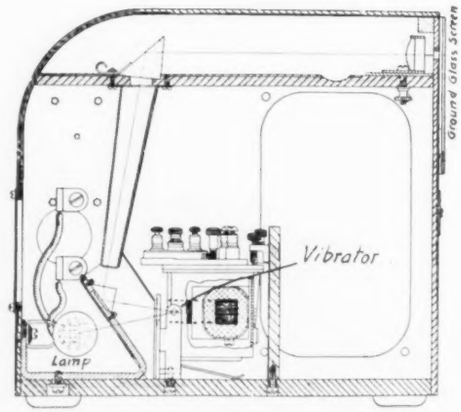


Fig. 49-11

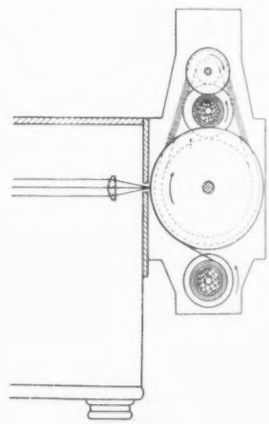


Fig. 49-12

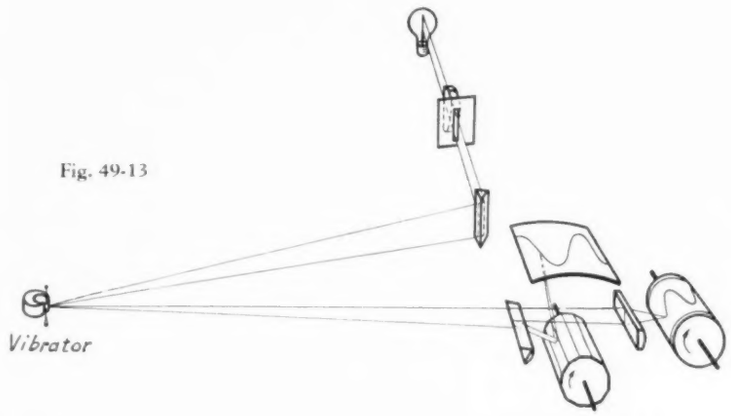
or a high-intensity incandescent lamp. Through a suitable optical train which includes the vibrator mirror, the light is brought to a point on a screen or photographic surface (as is shown in Fig. 49-11 which is a sectional diagram of the Westinghouse "Osiso"). The oscillating *spot* now traces a *line*

Where only a record is required (and this is the simplest case to begin with) a film is caused to move in a direction transverse to that of the line formed by the spot, so that the spot traces on the film a path representing the wave form under investigation. Fig. 49-12 (Westinghouse) shows the idea. In some designs the film is cut to a definite length and wrapped about a drum which is caused to rotate continuously, a shutter mechanism serving to admit the light spot to the film chamber for one revolution of the drum. In other designs the film is continuous, and the mechanism feeds through only sufficient length to provide the desired record. Sometimes bromide paper is used, simplifying the process of development and obviating the need for printing.

When it is required to make a visual examination of a periodic phenomenon, such as an a-c. wave-form, resort may be had to any one of a number of more or less distinct methods of making the wave appear to stand still for viewing. In an early design use was made of a white-surfaced rotating drum in the form of a cylindrical cam of spiral curvature. The spot projected upon its white surface showed a picture of the wave, with the illusion of its floating in space.

The method of rendering the wave visible in most modern oscillographs is shown in Fig. 49-13. The light beam is first passed through a condenser lens and a slit which serves to define its edges and produce a clear-cut image. A totally-reflecting prism then serves to direct the spot on the vibrator mirror, whence it is reflected, with the vibrator movements superimposed, to a prism or mirror by which it may be directed either upon the photographic film or on a rotating polygonal mirror. In some forms the beam is split, so that a portion of the spot is projected on each, making possible simultaneous viewing and

Fig. 49-13

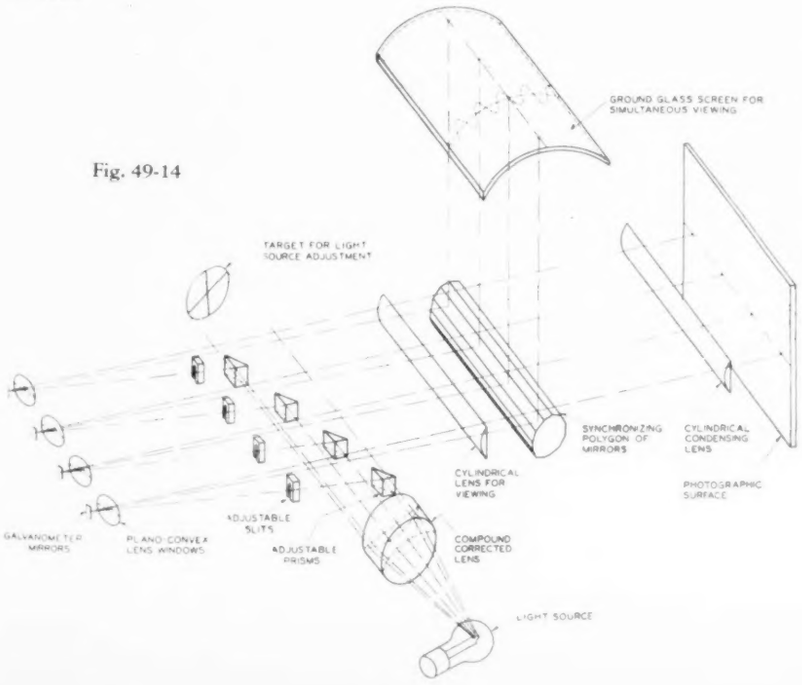


photography. The polygonal mirror has the effect of causing the spot to sweep repeatedly across a translucent screen; and by bringing the rotation of the mirror into synchronism with the movement of the vibrator, the wave will stand still, so that it may be observed, measured, and traced.

In some General Electric oscillographs, instead of a polygonal mirror, there is employed a single mirror oscillated by a cam. By giving the cam a "quick-return" action, it is possible to cause the spot to sweep in one direction over the screen during a large proportion of the total time and to return quickly in the opposite direction. The beam is momentarily interrupted as the mirror quickly reverts to its starting position, so that the return portion of the wave is cut off. Thus, with the motor in synchronism, a continuous stationary wave appears on the screen. This is the mechanical analogue of the now-familiar "saw-tooth" sweep of cathode-ray oscillographs (to be described in Section 8).

In some forms of demonstration oscillographs, provision is made for projecting the light spot on a wall screen, giving an image several feet high; but in the most modern forms the screen is on the side of the instrument, and the light intensity is sufficient to render the wave clearly visible from as far as 50 feet.

Fig. 49-14



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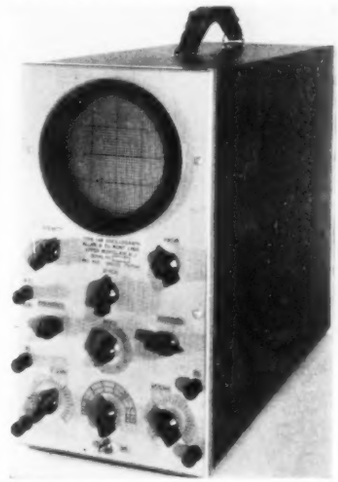

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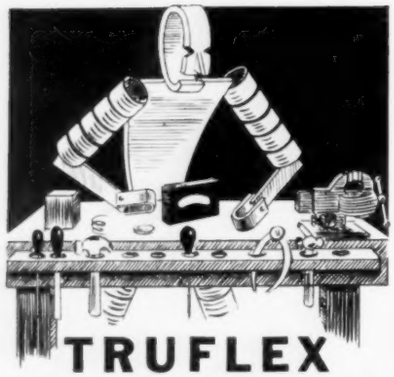

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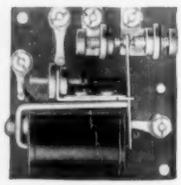
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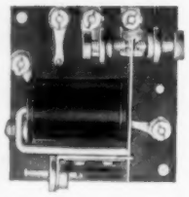
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(b) Multi-element Oscillographs

The usefulness of the oscillograph is vastly extended by the employment of a number of independent vibrators simultaneously projecting portions of the beam derived from the main source, on to a common surface as shown in Fig. 49-14 (Westinghouse). This makes possible the comparison of concurrent phenomena, and permits studying all matters of time sequence and phase relationship. For many years the standard number of vibrators for an oscillograph was three; but in recent models, six, nine, and even twelve, are used. The modern electromagnetic oscillograph is a most complete instrument, including many accessory devices whereby the instrument may be brought into action in proper timed relationship to transient or non-recurrent phenomena. Different forms are available for different classes of work; and while no mutually-exclusive classification is possible, there may be mentioned as classes, lecture-room, research, power plant, and sound laboratory models. To these may be added portable models, in which a number of accessory features are sacrificed to light weight and small dimensions; and high-voltage models, in which the vibrators and associated parts are provided with special insulation to enable use directly connected to ungrounded high-potential conductors.

5. Electromagnetic Class

(a) Forms of Vibrators

Though there have been mentioned several distinct principles whereby changes in the position of a beam of light may be utilized in oscillography, experience has shown a number of these to be of little more than academic interest with scant practical application in industry. The best-known and most widely applied of those principles which involve mechanical movement of parts of the instrument is the electromagnetic moving-conductor, in which a conducting fibre or loop vibrates in a magnetic field in response to currents which it carries.

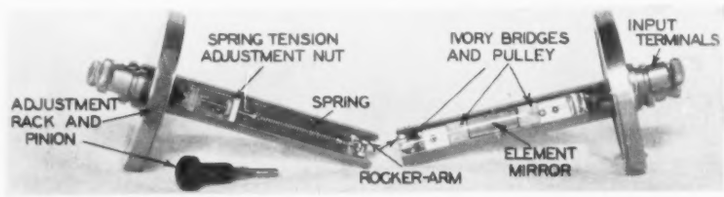

Fig. 49-15

Fig. 49-15 gives two views of the standard element used in most Westinghouse oscillographs. The operating principle of this vibrator has been made plain in Section 4, and was shown in Fig. 49-5.

A complete General Electric vibrator, of a form which gave most satisfactory service for thirty years and only recently has been superseded, is shown in Fig. 49-16. Here is seen the strip passing over bridges *B,B,* and around the ivory pulley *P* to the terminals *T,T*. Tension is maintained by a helical spring

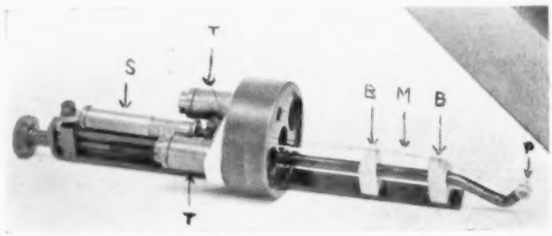

Fig. 49-16

in the small cylinder *S*, attached to the rod which carries the pulley. Adjustment of tension is effected by the knurled screw at the end of the frame. The mirror *M*, of silvered glass the size of a pin-head, is barely visible midway between the bridges. The strip (which is of a silver alloy) is 0.007 in. wide by 0.00075 in. thick. Its resistance is about 1 ohm, and its normal operating current approximately 100 milliamperes. This form of vibrator is now superseded by that shown in Fig. 49-17. While the principle remains unchanged, the mechanical improvement greatly facilitates convenience in use and provides an element more rugged and permanent in its characteristics than was

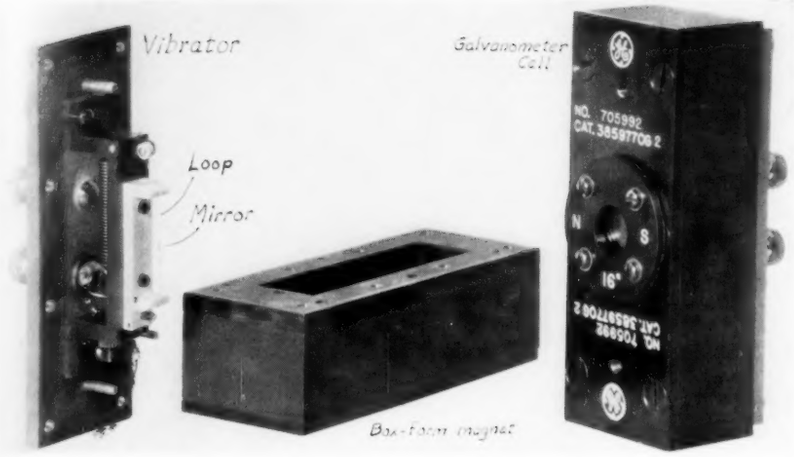

Fig. 49-17

the earlier form. The vibrating element carrying the mirror is mounted on the rear cover of the galvanometer cell, and is readily removable for examination.

The vibrator of the Cambridge (Duddell type) oscillograph is shown in Fig. 49-18. The pole-pieces of the magnet system form a part of this unit, making it possible to locate the strips and the mirror with great precision when stringing the vibrator. Interchangeable with this unit is the Cambridge *electrostatic* element, Fig. 49-19 (which was shown diagrammatically in Fig. 49-7). The front plate is swung to one side, exposing the vibrating filaments

Fig. 49-18

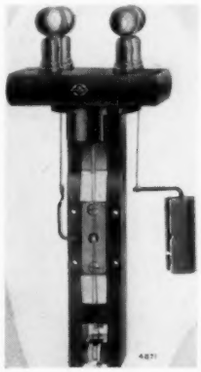

Fig. 49-19

Note—These three illustrations are exactly half-size.

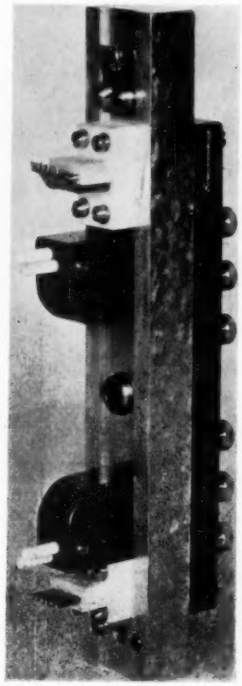

Fig. 49-20

and the mirror. Interchangeability of vibrator types permits any desired combination to be made up by the user. The electrostatic vibrator finds its particular application in voltage measurement on circuits of the power frequencies, where the available current is limited, but in general it not used where the vibrating loop type can be applied.

Fig. 49-20 shows a recent form of vibrator for an Einthoven mirrorless (see Fig. 49-4) string galvanometer as manufactured by Cambridge. This particular unit has twelve strips mounted in a common magnetic field, permitting a record to be made of as many variables. The fibres (stretched between the white pegs) are so small that they are barely perceptible in the original photograph.

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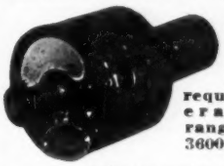

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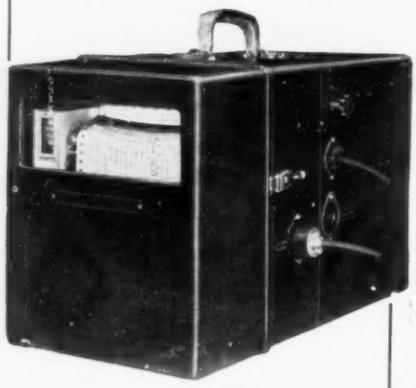

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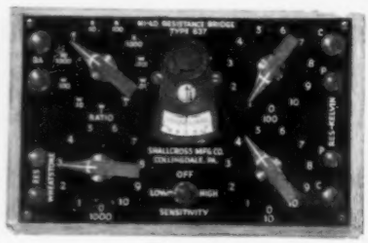

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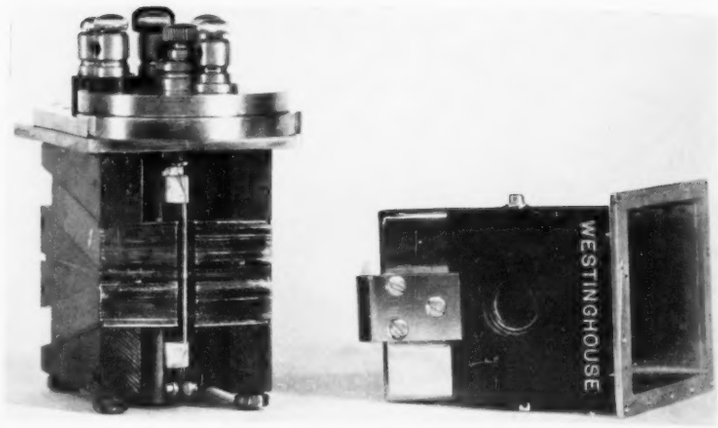

Fig. 49-21

Electromagnetic elements are available also in the electrodynamic form, where the magnetic field, instead of being unidirectional and of constant value, is produced by current in the circuit under investigation. If the vibrator of an element excited in this manner is subjected to voltage conditions there is produced a response representing the watts in the circuit. The wattmeter element may be used to record variations of power, and to picture the double-frequency characteristics of an a-c. power wave (see *Instruments*, Feb. 1934, page 32). A vibrator of this electrodynamic type, as produced by Westinghouse, is shown in Fig. 49-21.

To round out this discussion of electromagnetic vibrators, it is not amiss to mention an interesting instrument which might be called a "semi-oscillograph" and which employs the polarized-vane principle explained in connection with Fig. 49-2. In the Hall high-speed recorder[6] the moving element is a soft iron vane mounted rigidly at the end of a duralumin rod set at an angle to the flux path in a powerful magnetic field produced by the current under measurement. This instrument cannot follow all variations in the wave-form at commercial frequencies, but only provides a record of rapid changes in the value during transients. It records on a photographic film; and in speed and sensitivity its performance lies below that of a true oscillograph and above that of a high-speed curve-drawing instrument.

(b) Vibrator Assemblies ("Galvanometers")

Vibrator elements are generally grouped in a common mounting, so that a number of variables may be simultaneously examined and recorded. In the earlier type of General Electric oscillograph, of which the vibrator shown in Fig. 49-16 forms a part, the field is provided by an electromagnet system, the whole assembly of magnets and three vibrators being shown in Fig. 49-22.

[6] E. M. Tingley, The Hall High-speed Recorder, *Transactions A.I.E.E.*, Vol. 47, 1928, page 252. C. L. Hall, High-speed Recorder, *Transactions A.I.E.E.*, Vol. 47, 1928, pages 1017-1021.

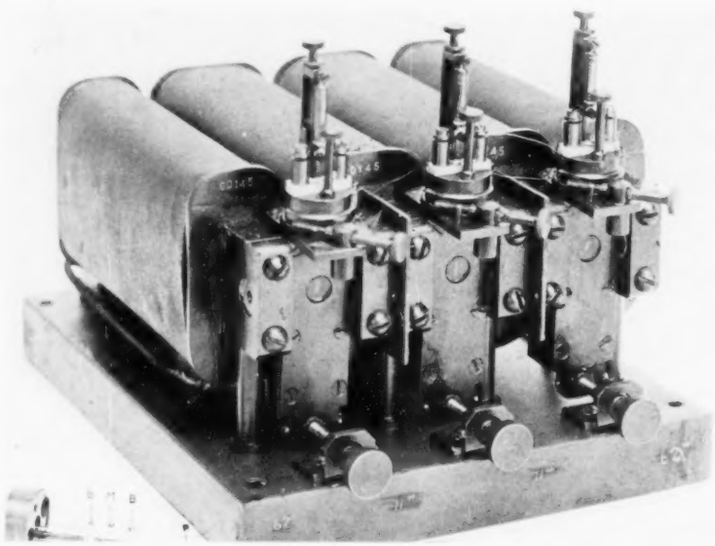

Fig. 49-22

Each vibrator is immersed in a transparent damping fluid contained in a cell clamped between the magnet poles, and having a small glass window in line with the mirror.

Modern advances in magnet alloys have made unnecessary the use of an electromagnet; and practically all recent designs of oscillographs are equipped with permanent magnets, making for lightness and compactness and facilitating the insulation of individual vibrators when used on high-voltage tests. This construction is used in the latest type of General Electric assembly, shown in Fig. 49-23. The galvanometers, while using a common optical system, are electrically and magnetically independent.

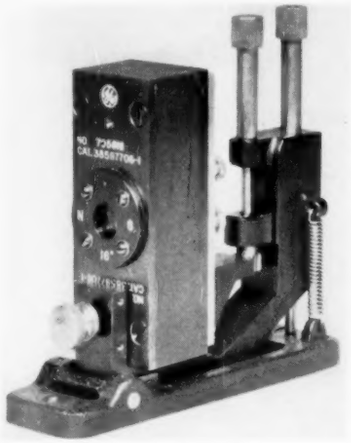

Fig. 49-23

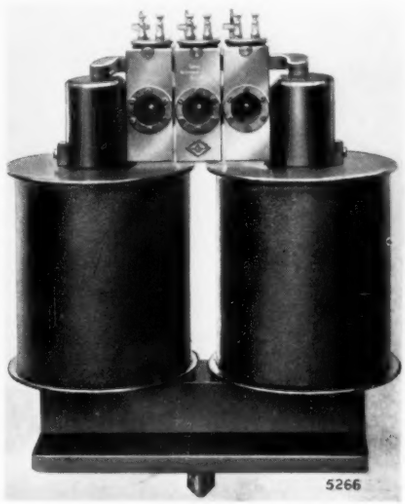

Fig. 49-24

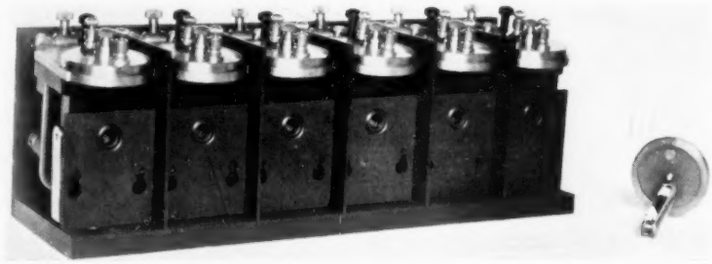

Fig. 49-25

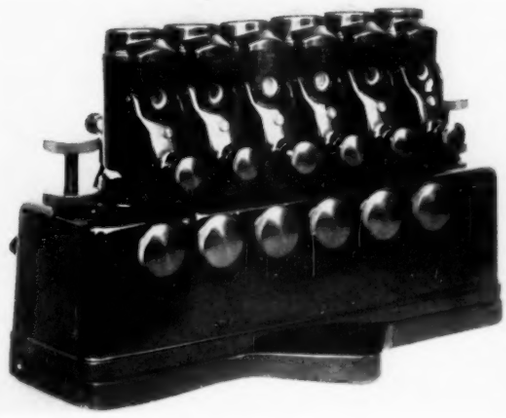

Fig. 49-26

A Cambridge three-element arrangement (with an electromagnet in this case) is shown in Fig. 49-24. It is available also in a six-element form, and also in a form having especially high insulation suited for direct connection to high-potential circuits.

The Westinghouse six-element assembly is shown in Fig. 49-25. (This is available also in a nine-element form.) Fig. 49-26 shows the six-element galvanometer used in the Siemens oscillograph.

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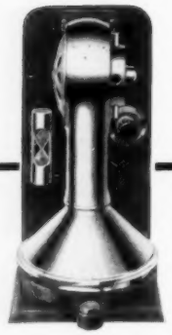

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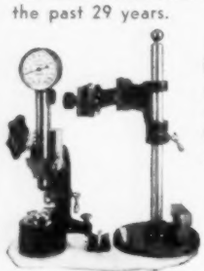

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INSTRUMENTS' BOOK SHELF

Handbook of Colorimetry. By Staff of Color Measurement Laboratory, Massachusetts Institute of Technology, under direction of ARTHUR C. HARDY. Preface by K. T. COMPTON. The Technology Press, Cambridge, 1936. Cloth, 10¼ x 13¼ inches. vi + 87 pages. Price $5.00.

An introductory chapter of 13 pages gives a clear and concise introduction to the subject. Three definitions of color are given: the objective as a definite substance, the physical as describing optical phenomena and the physiological or psychological referring to the sensation of the observer. For this handbook the physical definition is meant. Strictly speaking the field is largely of spectro-photometrics.

Standard illuminants are considered in terms of those of the International Commission on Illumination. For the present work Standard C has been adopted. Color specification in terms of mixing of three primary colors leads logically to standardization of color in terms of the data of Wright and Guild as calculated for the I.C.I. into values which do not require negative figures. The dependence of visual color on the light source is strikingly illustrated by spectral reflection curves of a blue-green paint in Figs. 1 and 8. That two colors may be the same in one light and different in another emphasizes the need for a universal color language such as the I.C.I. tristimulus values. By suitable treatment of the tristimulus values brightness can be eliminated as a factor in comparing colors. Representation of chromacity in terms of the cartesian system permits a clear exposition of the relation of dominant wave length and purity, even when the dominant wave length of a color is expressed in terms of its complement.

The comparison of sources of light, including specifications of I.C.I., standards A, B and C, is followed by tables of the energy distribution of those standards and spectral distribution of sunlight above the atmosphere and at noon in Washington. Spectrophotometry of homogeneous and non-homogeneous materials is explained in terms of Bouguer's (Lambert's) law and Beer's law, of which the first applies strictly but the latter becomes only an approximation at high color intensities.

Non-homogeneous transmitting materials or mat reflecting materials present special problems. Subtractive color mixture and additive color mixtures are followed by a table of complementary wave lengths. Determination of tristimulus values by the weighted ordinate method is facilitated by an example of a sheet of white paper and 13 pages of tristimulus values. The selected ordinate method is similarly accompanied by the tables of data. The trichromatic coefficients of the spectrum colors follow and the book concludes with 24 large-scale sections of the chromacity diagram.

For the physicist equipped by training and experience to use the data the book is priceless as presenting material in table and chart form which would otherwise require days, at least, to assemble, calculate and collate.

In a field which is growing so rapidly the author and his assistants are to be congratulated on laying such a firm foundation at this stage of its development.

—FOSTER DEE SNELL, *President, Foster D. Snell, Inc., Consulting Chemists, Engineers, Brooklyn, N. Y.* (7.2)-B-

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Colorimetric Methods of Analysis, Vol. I, Inorganic (Second edition). By F. D. SNELL and C. T. SNELL. D. Van Nostrand & Co., New York, 1936. Leather, 6x9¼ inches, 717 pages. Price $9.50.

While based on the data presented in the first edition, this edition is far more extensive in scope and brings the entire subject right up to date. It contains a valuable comprehensive survey of the colorimetric methods for quantitatively determining the metals, metalloids, inorganic radicals and hydrogen ion concentration. The newer turbidimetric and nephelometric methods are also included. Many of the biological methods involving the determination of inorganic constituents are critically reviewed.

The subject matter is clearly presented. The theory underlying the general methods employed, the degree of accuracy which might be expected of them, their limits as well as their applicability, are clearly and concisely stated and are supported by a comprehensive bibliography. Where conflicting evidence has appeared in the literature this is called to the reader's attention by the authors' comments.

The first seven chapters deal with the theory of colorimetric analysis and the methods and apparatus employed. Chapters VIII and IX treat of nephelometry, photometry, turbidity and the calculations involved. Chapters X through LXIII are devoted each to a metal, metalloid or radical; each containing a concise treatise of the specific method and apparatus involved, the method of preparing the sample and reagent, the procedure to be followed, the preparation of the reference standards and the accuracy to be expected. Chapters LXIV through LXVII are devoted to colorimetric hydrogen ion determination methods.

The book is unique in that it contains more than 100 illustrated descriptions of the various instruments used in colorimetric, nephelometric and photometric methods of analysis. The descriptions are concise, yet such that the reader soon finds himself planning new uses for the instruments. These and the 37 tables of data required for the preparation of the various standards, make available under one cover, information hitherto widely scattered and hard to find. The separate indices of these make the volume all the more valuable.

The book is comprehensive in scope and decidedly encyclopaedic and proceleusmatic in nature; a real contribution to that lusty young science of colorimetric analysis which is already controlling so many industries.

—ARTHUR SCHRODER, *Director of Technical Service, Chicago Apparatus Co., Chicago, Ill.* (7.2)-B-

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Elektrische Messungen (Electrical Measurements). By WERNER SKIRL. Walter de Gruyter & Co., Berlin & Liepzig, 1936. Linen, 6×8¼ inches, 802 pages. Price 15 RM.

This is a second edition of Volume 6 in a series of handbooks sponsored by the Siemens manufacturing interests of Germany. Although it is put forward only as a handbook covering the use of instruments and accessories made by the Siemens Halske Company, it is unusually complete and may be said to represent the highest type of technical literature.

The work is divided essentially into two parts, "Starkstrommesungen" and "Schwaschstrommessungen," which may be liberally translated as heavy-current measurement and weak-current measurement. Under the first of these heads the author has grouped measurements which may be made with direct-deflecting instruments; and under the second those (commonly known in American practice as "null" methods) which involve some form of balancing circuit and include a galvanometer or other form of balance detector. This grouping, however, is not absolutely rigid, and there has been no hesitation in transposing particular instruments or measurements in the interest of logical presentation.

In the first group are found instruments generally associated with measurements on commercial power systems, including a variety of types of current and power measuring instruments with their accessories, recording instruments, telemetering apparatus, system-regulators, and devices for testing cables and transmission lines. In the second section are treated those types of instruments found more generally in the laboratory and in communication engineering, including potentiometers and bridges, inductance and capacitance measuring instruments,

...ation testers, standardization apparatus and oscillographs.

...contents of the book are arranged in a most logical sequence, each section opening with a discussion of the magnitude to be measured and leading up through the principles involved in the method adopted, and dealing with all the types of instruments to be used. The 711 diagrams and drawings are particularly fine, and are grouped in a manner to give a condensed course in electrical measurements almost without reference to the text. Thus, a reader with but a scant knowledge of the German language may yet derive much information from studying the illustrations. The author has been prolific in his illustrative matter dealing with power measurement, presenting more than 100 drawings and diagrams dealing with wattmeters and their connections alone. Indexing is carried out in a particularly complete manner, there being four distinct indexes, occupying in all some 43 pages, so that it is but the work of a moment to find reference to any desired branch of elecrical measurement.

In a prefatory note it is stated that the first edition was translated into French and Spanish. There is no doubt that an English translation of the present edition would have a phenomenal appeal to students, teachers and users of electrical instruments; and since the apparatus treated in the volume represents the product of a single foreign manufacturer, the appearance of the work in the English tongue might have interesting commercial reactions upon the American builders of electrical instruments.

—PERRY A. BORDEN, *Research and Development Engineer, The Bristol Co., Waterbury, Conn.* (4.2)-**B-**

Phenomena in High-frequency Systems. By AUGUST HUND. McGraw-Hill Book Co., Inc., New York, 1936. Cloth, 6x9 inches, xvi + 642 pages. Price $6.00.

In his preface to this book, the author discusses the interplay between theory and experiment in the development of physics and emphasizes its profound importance. After illustrating this idea by a short historical sketch, he describes the purposes and content of the book as follows: " . . . In short, the coöperation between experimenters and theoretical thinkers led to most of the invaluable devices used in high-frequency systems today and it will probably be the same combination of workers that will lead on in the field. A book combining both experimental and theoretical reasonings should, therefore, be in order. Inasmuch as the title of the book is 'Phenomena in High-Frequency Systems,' not only high-frequency phenomena are dealt with, but also phenomena within parts of apparatus and systems which are used in the radio-frequency as well as in the communication field. It was the aim to give a thorough up-to-date discussion of phenomena occurring in high-frequency systems with many applications to problems arising in communication engineering."

It is obvious that the author has set himself a huge task not permitting, in a single volume, of completeness or perfection of detail. However, a useful book of well-indexed information has resulted. The relation of theory and practice is clearly brought out; many of the developments are carried from first principles to expressions useful in engineering calculations. The number and range of topics covered are prodigious:

Chapter I on "Actions and Effects in Space Discharge Devices" covers fundamental material as well as explanations of the actions in various types of tubes. Thermionic emission, space charge and secondary emission, ionization, cold electron emission, magnetron effect, and the photoelectric effect are all treated as effectiveiy as the space permits.

Chapters II to VII deal with generation, transformation, change in phase, frequency change, rectification, inversion and amplification of high frequency currents. Chapter VI on rectification and inversion deals with the low-frequency apparatus used in supplying d-c. power to the high-frequency circuits.

Chapter VIII on "The Theory of Electrostriction with Special Reference to Piezoelectricity in Quartz" contains design formulas as well as theoretical discussion.

Chapters IX to XIII cover "Electromagnetic Theory," "Theory of the Ionized Layer" (Heaviside-Kennelly Layer), "Lines of Long and Short Electrical Length with Special Reference to Antenna Problems," "Directive Systems" and "Theory of Recurrent Networks."

An appendix of "Useful Relations and Tables" contains a discussion of electrical units, tables of hyperbolic functions and short expositions of vector analysis differential equations and infinite series.

This book should be of prime value to the engineer who wishes readily accessible information on communication theory and devices.

The physicist seeking information on the present position of a theory or the latest developments in a field of communication practice is likely to be disappointed in his book. However, he is likely to find a summary of his topic with ample references to its literature.

—L. T. BOURLAND, *Research Laboratories, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.* (4.1)-**B-**

Industrial Instruments (Messgeräte im Industriebetrieb) By GUIDO WUNSCH & HANS RUHLE. Verlag Julius Springer, Berlin, 1936. Cloth, 6¼ x 9⅜ inches, 306 pages. Price 26.70 RM.

This comprehensive review of industrial measuring instruments is intended for use as a textbook and guide for the industrial user. The general principles of measuring and recording apparatus are first discussed in detail, after which the special processes and instruments used for measuring pressures, temperatures, the flow of fluids, the contents of containers, and the composition of gases are described.

In the introduction the authors state, "The ultimate purpose of instrumentation is not to try to get along with the least material and thus to increase the efficiency of a certain operation, but it should give a composite view of efficiency of the whole plant and thus indicate the possible improvements."

Few instruments of American manufacturers are illustrated or mentioned: Bailey, five; Foxboro and Leeds & Northrup, two each; Cochrane and Republic, one each.

RICHARD RIMBACH (1.2)-**B-**

Mechanical Tests for Engineering Materials. By A. M. ROBERTS. Draughtsman Publishing Co., Ltd., London, 1936. Paper 5½ x 8½ inches, 89 pages. Price 4s.

In his introduction the author states, "The excuse for introducing yet another publication on this subject is to be found in the need for a brief treatment giving concisely the methods and purposes of the more usual forms of test, which it is hoped will be sufficiently comprehensive to meet most of the needs of the designer or draughtsman without introducing details and arguments, which are only of real value to the person actually engaged in testing. The pamphlet is, therefore, written specifically for the engineer and draughtsman who, unfamiliar with testing methods, meets the problem of deciding what tests it is necessary to apply to the machine or structural part which he has designed and for which he wishes to insure a satisfactory performance under the service conditions with which he is acquainted."

The pamphlet describes various tests and testing machines (English): tensile, bend, hardness, impact, transverse on cast iron, fatigue, creep, tests on welds and cement, test procedure.

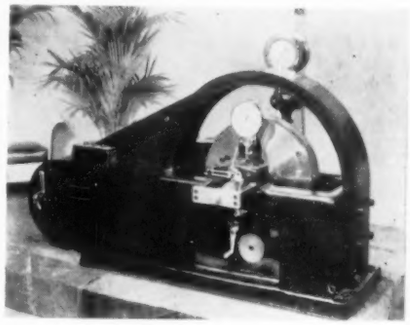
RICHARD RIMBACH (3.1)-**B-**

Radio Service Business Methods. By JOHN F. RIDER and J. VAN NEWENHIZEN. Published by RCA Mfg. Co., Camden, N. J., 1936. Paper, 6 × 9¼ inches, 218 pages. Free to service engineers dealing with RCA distributors.

Some topics: A Profit On Your Investment; What to Charge; Simplified Records and Bookkeeping, etc. Primarily, the authors seek to help the radio service engineer unfamiliar with bookkeeping.

—M. F. BIHAR (12.5)-**B-**

A NEW *Measurable Property* DISCOVERED IN METALS . . .



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QUESTIONS & ANSWERS

FOR YOUR DATA FILES

INSTRUMENTS receives a constant stream of questions, and answers most of them immediately. A selection of Q&A's, of general interest to most subscribers, and involving subjects which are NOT dealt with in readily-accessible sources, will be printed every month in this Department. Many of our immediate answers, no doubt, are incomplete; and we shall be pleased to print additional answers from readers in position to know methods and devices which have not come to our notice. One dollar will be paid for each supplementary answer printed in this Department.

D.C. to A.C.

Question No. 5 **Subject Index 12.1**

"There is no commercial a-c. supply in this district. We are contemplating the installation of recording instruments, telemeters and integrating meters having essential elements depending on small synchronous-motor drives of the electric-clock type. Higher prices are quoted for specials which do not incorporate the common 60-cycle clocks. In addition, we want to avoid having to depend on hand-winding a number of clock movements. Furthermore, some mechanisms will not operate without an a-c. supply. But the installation of an a-c. generator equipped with precision frequency control is out of the question. Have you any suggestions?"

A.—If you have already dismissed the idea of a line to your plant from the nearest frequency-controlled a-c. source, we suggest: (1) An electronic inverter utilizing the ripple in commercial d-c. supply from central stations tied in with inter-state a-c. systems. In such tied-in stations, the speeds of rotating units are said to be as constant as the shaft speeds of the out-of-town a-c. stations with which they are interconnected. Therefore, their ripple frequency keeps as good time as does the a-c. frequency. An electronic inverter for your purpose would be about the size of a shoe-box and its price would be less than the increased costs you mention. (2) The d-c. ripple frequency in your district may not be 60 c.p.s. In that case you would also require a frequency divider or a frequency multiplier. (3) If the ripple frequency of your d-c. supply does not keep time satisfactorily—which no doubt is the case if you generate your own power—you may obtain an a-c. supply (40-watts max.) from one of the inexpensive miniature motor-alternator type inverters recently brought out for operating modern a-c. radio receivers from storage batteries on farms. Such a device is so inexpensive that most of your appropriation can go for an automatic frequency control system. There are numerous types of frequency regulators.

Room Comfort Meters

Question No. 6 **Subject Index 2.08**

"For several years I have heard of investigations demonstrating that air temperature and humidity are not the all-important factors determining comfort, an equally important factor being radiation from hot or cold surfaces. Nevertheless, the readings of the same old wet-and-dry-bulb thermometers apparently continue to be given as the only scientific data in the latest published discussions of air conditioning; and the best psychrometers are now said to be the ones with wet and dry bulbs carefully shielded against radiation. Do you know whether any instrument has been offered on the market, or is about to be offered, which gives a truly scientific 'comfort' reading including the radiation factor?"

A.—Air-conditioning engineers recognize not two but four important factors: temperature, humidity, circulation and cleanliness. These pertain to *air*, which is what they chiefly have to deal with. It is true that one feels comfortable in a "warm-wall cold-air" experimental room but such air-conditioned rooms (with >50% of total wall area radiating by reason of concealed heating units keeping surface temperature at approx. 80°F.) are still rare. In most rooms of today, the effects of direct radiation on bodily comfort vary as one moves from place to place, depending on one's distance from window areas, steam pipes, etc. For determining humidity, those instruments are best which isolate samples of air and are shielded against radiation errors. There are in addition various forms of instruments designed to measure the combination of conditions to which a person is exposed in a room:

(1) The kata-thermometer, invented more than 100 years ago, is designed to be affected by air temperature, air motion and radiation to the same extent as a human body in which the blood temperature is normal: it is first heated to >100°F. and then placed on the hospital bed or other location under study, and the time to fall from 100°F. to 95°F., taken by stop-watch, is a measure of the combination of the three factors.

(2) The radia-kata-thermometer, brought out by Hill a few years ago, is used to determine *separately* the effects of radiation, convection and humidity.

(3) Various forms of wet-and-dry-bulb thermometers are designed to read directly in degrees of "effective temperature"—an H.S.H.V.E. term denoting combination of temperature, humidity and air motion.

(4) The Eupatheoscope, announced as "a recent invention by British scientists to determine the comfortable or uncomfortable character of the *air* in a room," is not that, but actually combines the functions of a kata-thermometer and of a calorimeter totalizing heat loss—from a simulated average clothed human body—to the surrounding air and heat exchange with radiating and absorbing surfaces in its vicinity. Its sensitive element is a hollow cylinder about 6" O.D. x 20", finished in black for sensitivity to radiation effects, kept at body temperature by an electric heating element. Its measuring element is an ordinary watt-hour meter, the registration of which is proportional to the chilliness of the room—not of the air alone.

WIND SPEEDOMETER

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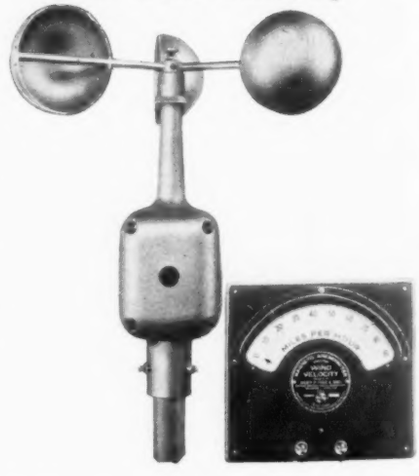

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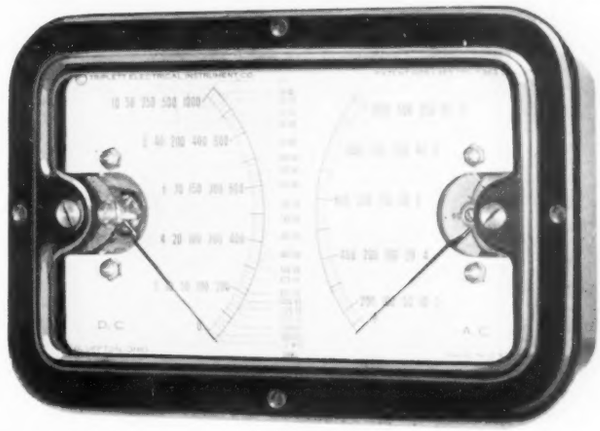

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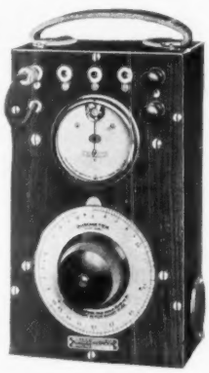

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Five dollars will be paid for every solution (or critical discussion clearly pointing the way to a solution) which is accepted for publication. Address Instrumentation Forum, 1121 Wolfendale St., Pittsburgh, Pa. Do not write on both sides of paper. Draw diagrams clearly, in black ink. Mail before January 15. Solutions and discussions accepted for publication will appear in the February 1937 issue.

Problem No. 2 Subject Index 2.08

MOISTURE IN GLUE

Consulting engineer advises us that he will pay $10 (in addition to our $5) for a solution acceptable to him of the problem of measuring moisture in wet and dry "glue pearls" or "pearl glue" by a RAPID method. Present method—oven drying of pea-like samples—is too slow in view of introduction of modern continuous drying process of manufacture. Ideal would be a continuous indication. Next best, a method taking a minute or so.

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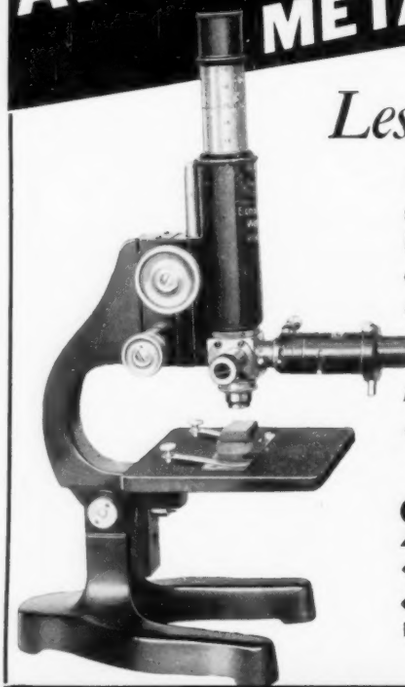
John L. Hodgson

IN the death of John Lawrence Hodgson those branches of science and industry concerned with instrumentation have suffered an irreparable loss. To the staff of *Instruments*, as well as to most of its readers, the news of his passig brings a personal sense of deep sorrow, for he was a collaborator and a valuable contributor to our columns. He died on August 14th, at his home, Eggington House, near Leighton Buzzard, England, at the early age of fifty-five, after a comparatively short illness, leaving a life record of valuable work in the engineering world. He was born at Lincoln in 1881, received his technical training at Nottingham University College, and took the B. Sc. degree in Pure Science at London University. Employed first by Messrs. William Walker, he patented a sewage apparatus. Then, after some months in coal mine work—in its surface and underground aspects—he joined Yarrow and Co., at Scotstoun, Glasgow, and was associated with the late Sir Alfred Yarraw in research which had considerable bearing on torpedo boat destroyer design and construction. In 1909 he joined the firm of George Kent, Ltd., of London and Luton, and became that company's Technical Advisor on all matters connected with the metering and automatic control of air, gas, and steam. He it was who designed the first Venturi air meters, which were installed by the Victoria Falls Power Company. In a period of service with his firm which lasted nearly twenty-five years and only terminated about eighteen months ago, he became internationally known to industrial and power plant engineers. Quite recently he was intimately concerned with the ventilation of the Mersey Tunnel and sent to the editor of *Instruments* a rough draft of an article on the special instruments he designed for that installation. As a pioneer worker in the use of the orifice for metering fluids he established for himself a world-wide reputation and contributed numerous papers to the technical societies and periodicals. For one of his papers he was awarded the Telford Medal by the Institution of Civil Engineers. Throughout his life he was inspired by the thought that scientific discovery and invention should be used for the service of man, and he abhorred waste in all forms. His book "The Great God Waste" was reviewed on the editorial page of our March 1934 issue.

He was one of the early users of the new familiar slogan "Poverty amidst plenty," and was one of the founders of the Engineers' Study Group, which was formed to study how and why the state of affairs implied by that slogan may be remedied, but his active and alert mind carried him often further than immediate practical policy, and he recently severed his connection with that Group.

ATTENTION METALLURGISTS!



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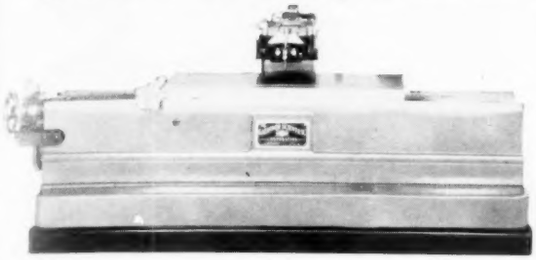

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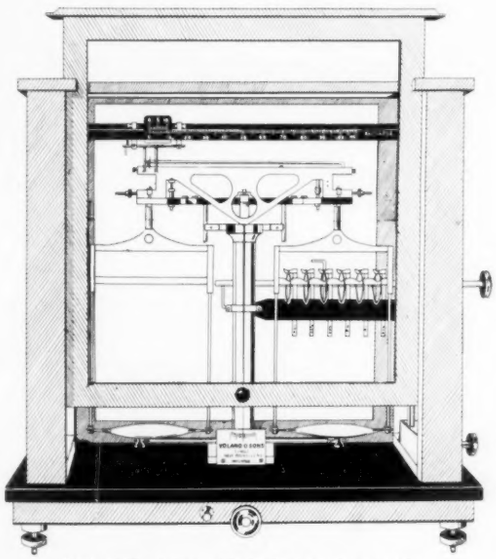

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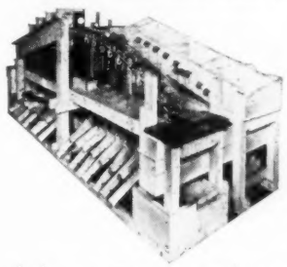
The analysis by models prior to the construction of the main structure, and tests to destruction of a full sized structure scheduled for abandonment have been employed to aid these studies.



• In Model Studies

Professor Beggs of Princeton has done much, his work including models of the towers of the Golden Gate Bridge constructed to exact scale in stainless steel; and a model of the world's largest floating drydock.

The Aluminum Company of America and the Bureau of Reclamation have studied models of dams, prior to actual construction followed by comparisons with the prototype.

Professor Large at Ohio State College has made studies of a skyscraper model. The U. S. Experimental Model Basin uses ship models for study. The Port of New York authority have studied models of the George Washington and Bayonne Bridges.

Other bridge structures such as the San Francisco-Oakland Bay Bridge have been studied in models.

Models have been made in celluloid, rubber compound, wires, stainless steel sheet—and the stress analysis made with dial gauges and very notably with Huggenberger Extensometers. (See illustration.)

Professor Beggs has attacked model studies from another angle—with the use of the Deformeter Gauges, wherein celluloid models are studied in two dimensions by introducing known deformations instead of loads, utilizing Maxwell's theorem and reading deflections with microscopes. Among many such uses was the study of the overhead system during the electrification of the Illinois Central Railroad at Chicago.

• Full Scale Tests

to destruction, or planned destruction, have been made on such structures as the Stevenson Creek Arch Dam and the Yadkin River Bridge. This latter was a full sized highway bridge. On these structures, the Electric Telemeter was used and in the dam test the Whittemore Strain Gauge came into use — a gauge in which the best reproducibility of readings was obtained.

The use of the Whittemore Strain Gauge has spread rapidly for stress analysis in the field. It was used on the Sidney Harbor Bridge by Dr. Bradfield, and is in use for such similar work as done by the American Bridge Company. It is used for arch tests, such as were conducted at the University of Illinois and Lehigh University, and in most of the major analyses of recent years.

Likewise, the rapid developments in aviation, automotive and railway equipment have advanced to an important place, the use of the Huggenberger Extensometer, the Scratch Recorder (for dynamic as well as static measurement), the Whittemore Strain Gauge and the electric recording instruments for stress studies, both under static loading and in reproductions of service conditions in live loading.

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MANUFACTURERS' NEW LITERATURE

In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm.

D375 **Radio Parts Tester.** 4-page 8½" × 11" bulletin describes new "QX-Checker" Type 110-A for rapid testing of coils and capacitors at radio frequencies. Boonton Radio Corp., Boonton, N. J.

D376 **Motor-Operated Controllers.** 4-page 8½" × 11" condensed Catalog G-10 describes and illustrates the principal classes of ATC mechanisms. Automatic Temperature Control Co., 34 E. Logan St., Philadelphia, Pa.

D377 **Improved Clarification of Raw Cane Juices.** 16-page 7¾" × 10½" Bulletin 709-C describes equipment which automatically regulates the addition of milk-of-lime to raw cane juice so as to hold it in the specified pH. This is a proportioning system which, in modified form, is suitable for numerous other industrial applications. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

D378 **Polyphase Detachable Meters.** 16-page 8½" × 11" Catalog Section 42-210 describes new types CS-2, CS-5, CS-7 and CS-8 meters and sockets suitable for their use including Types S-5, S-2, S-8. Applications, construction, operation, adjustment outline dimensions and wiring diagrams are included. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

D379 **Baldwin-Southwark** is the title of a new house organ, 8½" × 11", magazine style, of which Vol. I, No. 1, 32 pages, is designated as the "Centenary Issue 1836-1936" and contains articles on "The Founder" (Samuel V. Merrick), "Southwark," "De La Vergne," "I. P. Morris" and "Pelton." Baldwin-Southwark Corp., Paschall Station, Philadelphia, Pa.

D380 **Pinch Type D.P.D.T. Switch.** Small leaflet describes convenient laboratory switch which can be used also as a reversing switch. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

D381 **Shielded Capacitance & Conductance Bridge.** Single sheet folding to envelope size describes this device for capacitance, S.I.C. and power factor of dielectrics up to 50 kc. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

D382 **The Effect of Atmospheric Humidity on Unsealed Resistors, Causes and Remedy.** 12-page 8" × 10½" reprint of scientific article. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

D383 **Power Plant Instrumentation.** Broadside, folding to envelope size, describes briefly indicating and recording instruments, telemetering systems and automatic control systems. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

D384 **"Solving Industrial Crimes."** No. 13 of this series of 4" × 5½" booklets the case of the B. F. Nelson Manufacturing Co. Esterline Angus Co., Indianapolis, Ind.

D385 **Valves for Air-Operated Controllers.** 28-page 8½" × 11" Bulletin 214 discusses controlled valves of both the throttling and quick-acting "open-and-shut" type, as well as modern controller accessories for extending the practical application of automatic control. A detailed discussion of operating characteristics, specifications and dimensions of the "Stabilflo" valves for throttling control is included, with particular emphasis on the significance of the 50-to-1 flow rangeability. Other throttling control valves of the needle and butterfly type are also described, as well as the complete range of air-operated globe and poppet valves for open - and - shut control. Auxiliary equipment described includes the "Vernier Valvactor"; remote valve control; lubricator bonnets; diaphragm motor levers; pneumatic switches; air compressors, etc. Foxboro Co., Foxboro, Mass.

D386 **The Q X-Checker.** 4 page 8½" × 11" bulletin describes new instrument for testing, grouping and adjusting coils and capacitors at radio frequencies. Boonton Radio Corp., Boonton, N. J.

D387 **"Q Meter."** 4-page 8½" × 11" bulletin describes high speed instrument for measurements on coils, capacitors, resistors and other circuit components. Boonton Radio Corp., Boonton, N. J.

D388 **Surface and Needle Pyrometer.** 2-page 8½" × 11" leaflet describes portable thermoelectric pyrometer for numerous purposes, provided with different styles of thermocouple elements. Pyrometer Instrument Co., New York, N. Y.

D389 **Colorimeter.** 2-page 7½" × 10½" Bulletin "Col. 36" describes a comparison colorimeter of the Dubosq type modified by Hymans Van Den Bergh-Grotepass. P. J. Kipp & Zonen, Delft, Holland.

D390 **Apparatus for the Measurement of Dielectric Constants.** 6-page 7½" × 10½" Bulletin "Dipol 36" describes a new precision apparatus for dipole measurements for liquids, accessories for gases and solids, and miscellaneous accessories. P. J. Kipp & Zonen, Delft, Holland.

D391 **Development of the Precision Hydraulic Testing Machine.** 16-page 3¾" × 9" booklet presents a brief history and a non-technical description of modern principles. Riehle Division, Am. Mach. & Metals Mfg. Corp., 100 Sixth Ave., New York, N. Y.

D392 **The Ohmite News.** The November issue of this 2-page house organ contains a brief technical note on ratings of resistors, and several non-technical editorials. Ohmite Mfg. Co., Chicago, Ill.

D393 **Airguide Trio.** 4-page 3¼" × 6¼" leaflet describes a decorative combination of three instruments in one: thermometer, hygrometer and barometer. Thwing-Albert Instrument Co., Philadelphia, Pa.

D394 **Thwing's Foundry Visitor.** Vol. 2, No. 2 of this 2-page 8" × 10½" house organ contains article, "Specialty Bronze Founders Pour Castings to Size Without Machine Work." Thwing-Albert Instrument Co., Philadelphia, Pa.

D395 **The General Radio Experimenter.** The November 1936 issue of this 6" × 9" 8-page house organ contains a thorough technical article "Losses in Audio-Frequency Coils"; also a description of low-temperature-coefficient quartz plates. General Radio Co., 30 State St., Cambridge A, Mass.

D396 **Flow-type Gas Calorimeter.** Bulletin TS 3000, 24 pages and cover, contains detailed instructions, approved by National Bureau of Standards, on how to set up the apparatus and conduct an accurate test; also includes essential calorimeter tables reproduced from Bureau of Standards Circular No. 65, now out of print; describes the calorimeter, outlines test procedure; lists necessary precautions and significance of errors; includes a brief bibliography and information and calorimeter parts and accessories. Precision Scientific Co., 1750 No. Springfield Ave., Chicago, Ill.

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ADVERTISERS' INDEX

Adams, Hurl R. 344
American Meter Company A7
Ames Company, B. C. 344
Askania Regulator Company A9
Bailey Meter Company 328
Bakelite Corporation A1
Baldwin-Southwark Corp. 355
Bendix Marine Products Co., Inc. 330
Bristol Company Back cover
Brown Instrument Company A5
Chace Company, W. M. A7
Continental Electric Company 345
Cramer & Co., Inc., R. W. A10
Defender Automatic Regulator Co. A11
Dietert Company, Harry W. 350
DuMont Laboratories, Inc., Allen B. 345
Eppley Laboratory, Inc. 353
Federal Products Corporation 329
Ford Motor Co., Johansson Div. A7
Foxboro Company Inside front cover
Friez & Sons, Julien P. 352
Gaertner Scientific Corp. 355
General Plate Company 346
Gordon Co., Claud S. A10
Havs Corporation A9
Illinois Testing Laboratories, Inc. 328, 329
Johansson Gage Div., Ford Motor Co. A7
Johnson Service Company A11
Kurman Electric Company 346
Leeds & Northrup Company A6
Leitz, Inc., E. 354
Loewenberg, Dr. F. 354
Minneapolis-Honeywell Regulator Co. A5
Powers Regulator Company A9
Pyrometer Instrument Company 347
Rawson Electrical Instrument Co. 347
Review of Scientific Instruments A12
Riehle Div., American Machine & Metals, Inc. 351
Roller-Smith Company 353
Rubicon Company 348
Shallcross Mfg. Company 348
Shore Instrument & Mfg. Co. 350
Sigma Instruments, Inc. 349
Sundt Engineering Company 349
Taylor Instrument Companies A2-A3
Triplett Electrical Instrument Co. 353
Voland & Sons, Inc. 355
Weston Electrical Instrument Corp. Inside back cover
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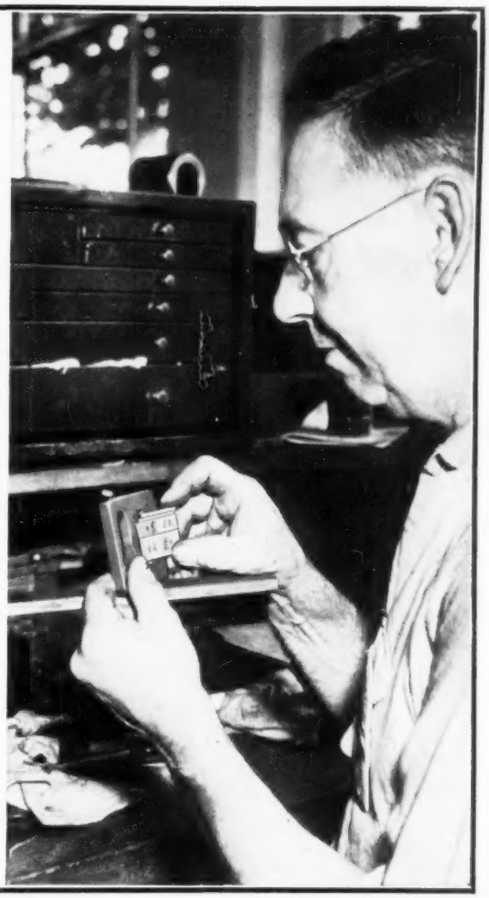

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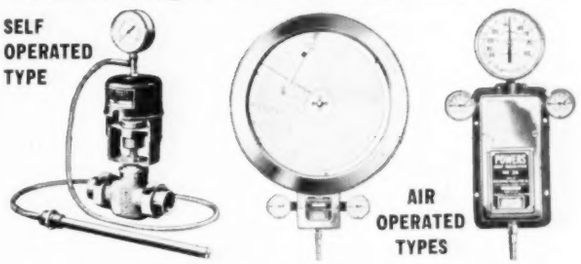

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Concluded from page 210

D212 **Ultra-Thermostat.** 4-page Bulletin HT254 covers construction, sensitivity and application of the Hoeppler ultra-thermostat. Temperature ranges are from —35° to +300° centigrade. Fish-Schurman Corp., 230 E. 45th St., New York City, N. Y.

D213 **Low-pressure Test Gage.** Bulletin No. 8 describes "inches of water column" test gage. Fisher Governor Co., Marshalltown, Iowa.

D214 **Dynamometers.** 4-page bulletin gives information on the "Hi-Eff" dynamometer for prime-mover B.H.P., torque, efficiency, and accessory testing. Taylor Mfg. Corp., 2330 W. Clybourn St., Milwaukee, Wis.

D215 **Tuning Indicator.** Form 1-36-22 gives principle of and wiring diagrams for new Taco device for use on radio sets. Technical Appliance Corp., 17 E. 16th St., New York City, N. Y.

D216 **Measurement of Gloss.** 4-page folder entitled "Instruments and Methods for Determining Gloss, Surface Texture Sharpness of Reflected Images and Bloom." Henry A. Gardner Laboratory, Inc., 2201 New York Ave., N. W., Washington, D. C.

D217 **Measuring Bridge.** Leaflet 6070 illustrates a handy pocket-size measuring bridge for resistances. A small standard pocket light battery is used. Herman H. Sticht & Co., 27 Park Place, New York, N. Y.

D218 **Phase Sequence Indicator.** Leaflet No. 537 describes new model in a Bakelite case, designed for all voltages from 50 to 600 volts and all frequencies from 20 to 60 cycles. Herman H. Sticht & Co., 27 Park Place, New York, N. Y.

D219 **Laboratory Supply Catalogue.** 636 pages of information on latest available merchandise for chemical laboratories. Exact specifications on sizes and prices; profuse illustrations; convenient index. Available only to recognized commercial and educational institutions having laboratories. The Chemical Rubber Co., 1900 W. 112th St., Cleveland, Ohio.

D220 **Automatic Fire Alarm System.** 4-page Bulletin 1501 describes "Sprinkla-stat" automatic fire alarm system. Gamewell Co., Newton, Mass.

D221 **Capacitors.** 24-page Catalog No. 127, said to be "the most complete condenser catalog ever issued" gives data on capacitors for industrial and transmitting applications. Cornell-Dubilier Corp., 4377 Bronx Blvd., New York City, N. Y.

D222 **Recording Thermometer and Operation Recorder.** Folder describes low-priced 24-hour recording instruments. Practical Instrument Co., 2717 N. Ashland Ave., Chicago, Ill.

D223 **Forged Steel Valves.** Bulletin 7020 describes new line of Hancock forged steel valves for all steam pressure ranges <1500 lbs. A number of distinctive features are claimed. Consolidated Ashcroft Hancock Co., Bridgeport, Conn.

D224 **Replacement Condensers.** 4-page Catalogue 5625 lists replacement capacitors according to set mfr. set model, characteristics, set mfr's part number, etc. Aerovox Corp., 70 Washington St., Brooklyn, N. Y.

D225 **Motor-operated Aspirating Psychrometer.** 1-page bulletin No. 501 describes this new instrument manufactured by C. E. Russell & Co., 121 Franklin St., Dayton, Ohio.

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BOOK SHELF

Continued from page 188

pilation of both theoretical and practical data on thermionic tubes and their varied uses. To *Instruments'* readers the 50-page thirteenth and final chapter on "Industrial Applications of Vacuum Tubes," containing thirty-nine examples with thirty-three circuit diagrams and ten other illustrations, will no doubt prove the most interesting. Let it be noted that under this "Industrial" chapter head the authors include a six-page discussion of "radio surgery" (*i.e.*, the therapeutic as well as the surgical uses of high-frequency currents), three pages on acoustics, four on "radio compasses" and a final half-page on metal shields for radio (not industrial) tubes which belongs in Chapter II, "Construction of Vacuum Tubes," certainly not in that "Industrial Applications" chapter.

Many classes of readers can derive benefit from this diversified work. Those whose training did not include a study of thermionic phenomena will find that the 137-page Chapter IV on "Vacuum-Tube Action" comes close to being the "ideal" text for their instruction as well as a useful reference which need not be studied. On the other hand, it is undoubtedly for readers in the radio, television and allied fields that the authors prepared Chapters VI to XII on Testing Vacuum Tubes, Vacuum-tube Installation, Use of Vacuum Tubes as Detectors, as Rectifiers, as Amplifiers and as Oscillation Generators, and Television Tubes.

This leaves two chapters on which we have not yet commented: the third, on "Fundamental Electrical Relations," presents not only a good foundation of electrical theory but gives examples and describes the practical design and commercial construction of several devices. The fifth, "Radio Meters and Measurements," may be of interest, one supposes, to service men who desire to know some of the principles underlying the operation of the instruments they use, as well as to persons who have not taken a high-school electricity course or its equivalent. The tone of this chapter appears to be too varied: here elementary data reminiscent of the useful book "Industrial Electricity and Wiring" by the same authors; and there sentences such as "The harmonic content of the output varies with the impedance of the load," which were copied with few changes from publications of the General Radio Co. issued for trained users of high-frequency instruments.

Not that the reviewer objects to incorporating into a technical book the *substance* of technical descriptions and discussions published by manufacturers whose staff engineers and scientists are recognized authorities. On the contrary! But in a book designed to appeal to many classes of readers, the elementary chapters should be understandable by novices and the advanced chapters free of "writing down." This book contains both these kinds of flaws. In the final chapter—the one on industrial applications—we find this: ". . . the light beam is refracted, meaning that its direction is changed, . . ." and other "in-case-you-don't-know" touches which are superfluous in that final chapter.

These, too, are minor shortcomings, inevitable in the process of hastily rewriting a new edition to keep up with a rapidly changing art. On the whole, the authors have done an excellent job. The 485 illustrations deserve favorable mention: they include many line drawings painstakingly made from photographs to bring out details that would be lost in printing half-tones on uncoated paper. Numerous tables and graphs in the body of the book and in the 22-page appendix contribute to the volume's value as a reference on modern tubes and their applications.

M. F. BÉHAR (5.4)-B-

ADVERTISERS' INDEX

	Page
American Meter Company	A9
Amthor Testing Instrument Co.	196
Bailey Meter Company	176
Baldwin-Southwark Corporation	194
Bausch & Lomb Optical Company	Inside back cover
Bristol Company	Back cover
Brown Instrument Company	A14
Burling Instrument Company	202
Calibron Products, Inc.	A11
Chace Company, W. M.	A9
Clifford Mfg. Company	182
Commercial Engineering Labs.	182
Continental Electric Company	202
Dietert Company, Harry W.	203
Eppley Laboratory, Inc.	A11
Federal Products Corp.	193
Fish-Schurman Corp.	200
Ford Motor Co., Johansson Div.	A7
Foxboro Company	Inside front cover
Friez & Sons, Julien P.	177
Gaertner Scientific Corp.	196
General Electric Company	A5
General Plate Company	203
General Radio Company	A9
Glass Engraving Company	201
G-M Laboratories, Inc.	180
Gordon Co., Claud S.	A12
Illinois Testing Labs., Inc.	208
Johansson Gage Div., Ford Motor Co.	A7
Kurman Electric Company	204
Leeds & Northrup Company	A6
Leitz, Inc., E.	178
Littelfuse Laboratories	A10
Lufkin Rule Company	195
Mason-Neilan Regulator Co.	A13
Minneapolis-Honeywell Regulator Co.	A14
Ohmite Manufacturing Co.	A7
Pfaltz & Bauer Co., Inc.	204
Pioneer Instrument Company	179
Powers Regulator Company	A7
Pyrometer Instrument Company	205
Rawson Electrical Instrument Co.	205
RCA Manufacturing Company	A9
Republic Flow Meters Company	179
Review of Scientific Instruments	196
Riehle Div., Am. Mach. & Metals Mfg. Corp.	195
Roller-Smith Company	A11
Rubicon Company	206
Scherr Company, George	194
Shallcross Mfg. Company	206
Shore Instrument & Mfg. Co.	208
Sigma Instruments, Inc.	207
Standard Electric Time Co.	207
Starrett Co., L. S.	194
Taylor Instrument Companies	A3
Triplett Electrical Instrument Co.	A11
Westinghouse Electric & Mfg. Co.	A2
Weston Electrical Instrument Corp.	A1
Winslow Engineering Company	208

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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INDEX TO VOLUME 10 — 1937

January 1-30	April 87-116	July 169-192	October 249-272
February 31-60	May 117-144	August 193-220	November 273-292
March 61-86	June 145-168	September 221-248	December 293-318

SUBJECT INDEX

A-c. Instruments, Portable Dynamometer Type.... 5
A-c-d-c. Instruments, Astatic Dynamometer Type Portable 10
Acoustic Pick-up, Small-angle All-range..... 250
Albert, N. J., **Instruments'** Readers at Work..... 294
All-wave Power-line "Filterette"..... 158
Ammeter, Clip-on 5
Analyzer, Autographic Audio-frequency..... 35
Analyzer, Automotive Engine..... 304
Analyzer, Circuit 229
Analyzer, Direct-reading, A.c. & D.c..... 92
Anemometer, Direct-reading, Filter Attachment for 94
Artificial Daylight Source..... 150
A.S.M.E. Fluid Meter Committee..... 156
Atomic Structure in relation to Hardness..... 68
Attenuator, Constant-impedance Output..... 36
Audio-frequency Schering Bridge..... 122
Automatic Room-temperature Control, Method of Inherent Time-lag Compensation..... 239

Balancing Equipment, Improved Davey Portable.. 94
Barmore, Edwin W., **Instruments'** Readers at Work 194
Barometer 225
Battery Eliminator 198
Battery Life Tests, Storage..... 154
Binocular Loupe 223
Boiler Water pH Instrumentation..... 195
Bridge and Analyzer, Condenser..... 259
Bridge, Portable Wheatstone..... 4
Brinell Instrument, Portable..... 300

Cable Power-factor Measuring Equipment..... 223
Caliper, Slide 281
Calorimeter, Gas 91
Capacitor, 3-dial Shielded Mica..... 147
Capacitors, High-voltage Oil..... 201
Cathode-ray Oscillograph Applications..48, 72, 103, 313
Cathode-ray Tubes 9
Cathode-ray Tubes, Commercial..... 267
Cathode-ray Tube Screen Material, Black & White 65
Cathode-ray Tube, Two-inch..... 178
Chamberlin, E. J., **Instruments'** Readers at Work 294
Circuit Breaker, Auxiliary..... 7
Circuit Breakers, Oil..... 9
Clarity Tester 128
Clay Washer 96
Combustrol 255
Comparator Gage 127
Condenser Kit, Oscilloscope..... 90
Condenser Replacements, Universal..... 64
Conductivity Bridge, Portable..... 255
Constant-weight-rate Feeder 197
Control Applications, Selection of the Correct Valve Types and Sizes for Automatic Flow..... 75
Control, Burner 254
Controller for Electric Furnaces, Throttling..... 298
Controller for Machine Tools, Hydraulic..... 97
Controller, Pyrometer 252, 253
Controllers, Air-operated Temperature and Pressure 62
Controllers, Cycle and Mercury Switches, Time... 5
Controllers, Stoker 6
Controller, Time Cycle..... 126
Control, Oven 274
Control, Pressure 275
Controls, Midget (Rheostats)..... 282
Control System 275
Control System, Automatic Moisture-content..... 93
Control Unit, Boiler..... 253
Control Unit, Temperature..... 66
Control, Volume (Rheostat)..... 275
CO_2 Recording Equipments Using Saturation Method 122
Core Permeameter 65
Core Porometer 64
Counter, Cycle 277
Counter, Mechanical 224
Counters, Electric 62, 230
Counter, Stroke 92
Cummings, Stanley Robinson, **Instruments'** Readers at Work..... 118

Dial Indicator, Universal-swivel..... 174
Diaphragm-motor 173
Dielectric Measurements, Low Loss..... 224
Direction-finder Loop 257
Dry Cells, High-capacity..... 125

Electrical Instruments, Three-inch Size Panel Type 63
Exploration Devices, Earth.....149, 289
Explosion pressures 28

Feeder, Dry Chemical Metering..... 304
Feeder, Metering Solution..... 121
Feed-water Control, Two-element..... 222
Ferguson, Patrick A., **Instruments'** Readers at Work 2
Fetz, Erich, **Instruments'** Readers at Work..... 194
Filter for Photronic Cells..... 38
Flow Integrator 199
Flow Measuring and Integrating Equipment, Null-method 35
Flow Meters, Electric..... 37
Flowmeter, Electrically-operated 124
Flowmeter for High Pressures, Multiple-orifice.... 257
Flowmeter, Multiple-orifice for High Pressures.... 227
Flow Nozzle Contours at Bureau of Standards, Determining 157
Flow Nozzle Research..... 156
Flow proportioning and sampling..... 25
Formaldehyde Gas Detector.....220, 268
Frequency Modulator 196
Fuel-om-eter, Automotive 34
Furnace Warm Air Control, Twin..... 202

Gage, Diaphragm-seal 67
Gage Laboratory at N. Y. U., Army's..... 135
Gage, Multi-pointer, Pressure..... 32
Gage, Paint Thickness, Electronic..... 250
Gage and Pump, Superpressure..... 254
Gage, Refinery 304
Gas Analyzer, Exhaust..... 173
Gas Valve, Magnetic 199
Gear Measuring Wires..... 150
Geophysical Prospecting, Electrical Equipment.... 128
Glass Strain Analyzer..... 147
Good Housekeeping Institute, **Instruments'** Readers at Work..... 88
Grid-controlled Gaseous Discharge Devices, Notes on Applications 45

Hardness and Hardness Measurements..12, 41, 68, 98, 133, 161, 182, 208, 237, 265, 286, 311
Hardness, Atomic Structure in relation to..... 68
Hardness Measurements, Underlying Conditions... 98
Hardness Methods, Scratch..... 182
Hardness Tester, Penetrometer..... 198
Hardness, Theories and Definitions of..... 41
Hardness, Wear Resistance in relation to.....133, 161
Hill, G. L., **Instruments'** Readers at Work..... 294
Humidity, Furnace, Measuring.....189, 244

Illuminators, High Intensity..... 176
Indicators, Universal-swivel 252
Ink, Heat-sensitive 299
Instruments, Electrical, Rectangular 257
Instruments for Production-line Tests of Motor Windings and Assembled Motors..... 307
Insulation-Resistance Test Set..... 195

Joints, Metal-clad 3

Knopp, Otto A., **Instruments'** Readers at Work.. 294

Lighting Control 300
Lindbladd, W. N., **Instruments'** Readers at Work 294
Liquid Level Indicators, Installing..... 210
Locating Buried Treasure.....245, 289
Lubricants, A Method of Measuring the Non-viscous Coefficient of Friction of..... 185

MacIntyre, A. D., **Instruments'** Readers at Work 294
Magnifier, Binocular, Head..... 198
Maximum Demand Tester..... 196
Measuring Engine, 14" x 17"..... 200
Measuring Engine, Universal..... 7
Megohm Bridge 256
Melting Point Apparatus..... 153
Memory Machine 146
Meteorological Instrument Assemblies for Airports 178
Meter, Brightness 90
Meter for Furnace Combustion Control, Fuel..... 3
Meter, Fuel Oil..... 96
Meter, Liquid Gravimetric..... 67
Meters, Air with Pitot-static Heads..... 67
Meters, pH Glass Electrode..... 63
Meters, pH Portable..... 66
Meter Tester, Portable Torque..... 91
Microscope Comparison, Applications..... 283
Microscopes, Wide-field Binocular..... 126
Modulation Monitor 8
Modulator, Frequency 298
Moisture determination in glue..... 56
Moisture Meter 226
Molding Automatic 281
Monochromatic Light Source..... 149
Motion-study Camera and Projector, Improved.... 8
Motor for Telemetering, etc., Position-type..... 33
Motor Stirrer 223
Motor Testing, on production line..... 307
Multimeter, D-c., Ultra-sensitive..... 298
Multimeter, Radio Set..... 32

New Method of Instrument Application 180
Noise Analyzer, Line..... 259
Noise in Industry..... 231

Ohmmeter, Direct-reading Switchboard Models.... 148
Oil Meter & Control Device..... 120
Orifice Fitting 224
Oscillator, Audio 97
Oscillator, Converter Test..... 230
Oscillator for Cathode-ray Oscillograph..... 39
Oscillograph 279, 301
Oscillograph Applications 72
Oscillograph Applications, Cathode-ray....19, 136, 163
Oscillograph, Cathode-ray 3, 38, 65
Oscillograph, Cathode-ray, Midget..... 64
Oscillograph, Three-inch 121, 223
Oscillograph, Five-inch 259
Oscillographs, High-Voltage 213
Oscillograph Using 1" or 2" Tubes, Cathode-ray 123
Oscillography 21, 51
Oscillography Errors, Cathode-ray..... 186
Oscilloscope 303
Oscilloscope Condenser Kit..... 90
Oscilloscopes Using 2" Tubes..... 122
Oxygen reaction rate.....27, 84

Pacific Gas & Elec. Co.'s Laboratory..... 294
Paints, Thermometric 65
Panel Instruments, Miniature, Electric..... 92
Photoelectric Control for Removing Skew from Cotton Cloth 121
Photoelectric Counting & Sorting, Rapid..... 302
Photoelectric Reflectometer 125
Pipe & Cable Detector..... 195
Plug-in Instruments 152
Polariscope 304
Polariscope, Photoelastic 151
Polarizing Device for Microscopes..... 304
Polarizing Unit for Microscopes..... 298
"Polaroid" Units 279
Polisher, Metallographic 179
Potentiometer, Air-operated Control.....251, 278
Potentiometer, Recording, Photoelectrically Balanced 95
Potentiometer, Round-chart 97
Potentiometer, Self-balancing 172
Pressure Instruments, Absolute..... 276
Print Hanger 225
Process Timer, Flexible..... 151
Projection Equipment for Map Making, etc..... 127
Pump Controls for Elevated Tank Systems..... 176
Pump Efficiency, Determining.....139, 188
Pyrometer "Bioptical"..... 250
Pyrometer, Diesel Engine..... 303
Pyrometer for Diesel Engine Exhaust, Multi-Point 127
Pyrometer, Industrial Radiation Receivers..... 123
Pyrometer, Micro Optical..... 302
Pyrometer, Portable 149, 277
Pyrometer, Portable Self-contained Immersion..... 39
Pyrometer, Rolling-mill 196
Pyrometric Control, Anti-hunting Device for..... 126

Recorder, Aircraft Operation..... 173
Recorder-Controller, Electric-contact Type..... 299
Recorder-controllers 302
Recorder-controllers, Bridge Round-chart..... 172
Recorder-controllers, Color numeral-printing 280
Recorder, Furnace Atmosphere..... 34
Recorder, Photoelectric, Double..... 146
Recorders, Gas-analysis, Portable..... 7
Recording Instruments in Philadelphia Gas Manufacture 263
Rectifier Mercury 177
Regulators for Alternator Voltage, Electronic..... 177
Regulator, Tank 256
Regulator, Voltage, Manual..... 11
Relay for Synchronous Machines, Out-of Step..... 10
Relays and Solenoids..... 34
Relay, Sequencing 283
Relay set, Portable..... 8
Relays, Small 62
Relay, Solenoid with Mercury Switch..... 276
Relay, Speed-regulating 37
Relays, Photoelectric 40
Relays, Time-delay 197
Relay-transformer Sets 151
Relay with Voltage Restraint, Directional..... 299
Resistance Bridge, Wide-range Vacuum-tube..... 261
Resistor 250
Resistor, Metal-tube Ballast Replacements..... 5
Resistors, Carbon 260
Resistors, Multi-unit Gang..... 174
Resistors, Plug-in 4
Resistors, Vitreous Coxet..... 179
Resonoscope 298
Rheostat 197
Rheostat, One-kilowatt 63
Rotameters, Improved 250

Scale Cut-off, Universal Photoelectric..... 278
Scales, Conveyor and Remote Recording Features.. 93
Schering Bridge, Modified..... 256
Schneider, W. R., **Instruments'** Readers at Work 294
Scratch Hardness Methods...182, 208, 237, 265, 286, 311
Screen Material, Cathode-ray Black & White..... 65
Signal Generator 64, 274, 282
Signal Generator, R-F..... 230
Sine Curve Plotter..... 153
Sketch Pad Set..... 198
Sound Apparatus 260
Spacer Ring in Convex-lens Elements, Length..... 283
Spectrograph 253
Spectrophotometer, Abridged 152
Spectroscopy in the Metal Industries..... 129
Speedometer, Electric 148
Speed-torque autographs 3, 108, 164
Spooner, Thomas, **Instruments'** Readers at Work.. 2
Springer, William M., **Instruments'** Readers at Work 170
Starters, Contactors, Magnetic..... 6
Stiffness Tester 257
Stirrer, All-glass 229
Stirrer, Motor 223
Surface Plate, Three-Angle..... 96
Surface Profile, Recording 269, 311
Switchboard Instruments, Six-inch A-c. Surface mounting 93
Switches, Instrument 36
Switches, Rotating-cam 91
Switch, Low-water Cut-off or Alarm..... 9
Switch, Vapor-proof "All-position" Plunger-actuated 150
Switch, Voltage, Super-sensitive Line..... 195

Tachometer, Normal Rate..... 91
Telemetering, Pneumatic 242
Telemetering Systems, Pneumatic..... 222
Temperature Controller, Indicating Model..... 254
Temperature Controller, Remote Re-setters..... 280
Temperature or Pressure Controllers..... 149
Temperature Recorder, Traveling Type Oven..... 253
Tester, Asphalt 9
Tester, Battery 36
Tester Cabinets 257

Tester, Car Ignition 40
Tester, Finish 227
Tester, High-velocity Impact 11
Tester, Line Insulator 38
Tester, Multi-purpose 37
Tester, Paper Formation 7
Tester, Paper Penetration 7
Tester, Portable Meter Torque 91
Tester, Radio 226
Tester, Radio Set 276
Tester, Set 302
Tester, Standardized Sieve-shaking for Cements, etc. 94
Testing Machine, Torsional Damping 251
Thermal Conductivity of Aircraft Fuselages 165, 218
Thermometer, Back-stem Dial 177
Thermometer, Floating 282
Thermometer, Refrigerator 175
Thermometer, Three-inch Dial 255
Thermometers, Dairy Scale-range 253
Thermometers, Dial 6
Thermometers, Sealed Thermal System 252
Thermoregulators 301
Thermostat, Day-night 175
Thermostat, Immersion 32
Thermostat, Room, Pneumatic Submaster 303
Thermostats 259
Thermostats, Crystal Oscillator 276
Thomson, Elihu (obit.) 111
Throttling Electric Heat 305
Time and Frequency Standard 128
Time cycle, automatic 84, 138
Time-operation Analyzer 175
Time-operation Analyzers 174
Timer, Automatic, Sense-of-touch-operated for Dark-rooms 285
Time Recorder 304
Timer, Furnace Firing Reversal 258
Timer, Photoelectric Portable 308
Timer, Portable 301
Timer, Production 92
Timer for Reversal of Firing, Automatic 177
Time Switches 4
Timing Devices, Motor-operated 11
Tire Traction Efficiency, Recording 315
Training Your Own Instrument Men 15
Transformer-rectifier Unit for 6-volt D-c Supply 176
Transformers, Multiple-ratio 148
Transformer, Variable 200
Trimetal, Thermostatic 32
Tube Checker 173
Tube Tester (Radio) 151
Tube, Ultra-high-frequency 225
Tucker, Wilmer Harland, **Instruments'** Readers at Work 118

Valve Control, Air-operated 153
Valve, Electric 258
Valves, Gas, Magnetic 274
Valve, Solenoid Trip Gate 64
Valves, Redesigned 251
Valve Types and Sizes for Automatic Flow Control Applications 75
Vibration Pick-up, Crystal 90
Vibrometer 302
Voltage Divider Components 198
Voltage Regulator 178
Voltage Regulator, Generator 37
Voltage Regulator, Manual 300
Voltage Regulator, Vibrating Type A-c 302
Voltmeter, High-voltage 39
Voltmeter, High-voltage High-frequency 36
Volt-ohm-milliammeter 10, 201
Volume Limiter, Automatic 178

Watch "Four-in-one" ..... —
Water Circulator 252
Water hammer pressure determination 56, 108
Water Level Recorder 120
Watthour Meter 300
Watthour Meter Testing Equipment 258
Weigher-feeder, Automatic Intermittent 40
Weighing Hopper, Dustless 147
Weighing Hopper, Illuminated 93
Welder Control, Ignitron Seam 122

X-ray Diffraction Tube, Cold-cathode 274

AUTHOR INDEX

Aerovox Corp. 90, 201, 259, 260
Allen Electric & Equipment Co. 34, 36, 40
Allen, James S. 108
Allis-Chalmers Mfg. Co. 37
American Instrument Co., Inc. 149, 152, 254, 302
American Machine & Metals, Inc., Riehle Div. 11
American Transformer Co. 11, 200
Askania Regulator Co. 120
Automatic Temperature Control Co. 177, 258

Bailey Meter Co. 32, 124
Baird Associates 258, 274
Ballou, Richard P. 188
Barkon-Frink Tube Lighting Corp. 150
Barss, Knobel & Young, Inc. 3
Batcher, Ralph R. 19, 48, 72, 103, 136, 163, 186, 213, 267, 313
Bausch & Lomb Optical Co. 126, 223
Bean, Howard S. 156
Behar, M. F. 1, 2, 21, 31, 51, 61, 87, 88, 117, 118, 145, 169, 170, 193, 194, 221, 273, 293, 294
Behr, Leo 39
Belfield Co., H. 153
Berry Asphalt Co. 9
Biddle Co., James G. 148
Black, John F. 218
Boonton Radio Corp. 224, 230
Borden, Perry A. 21, 51
Bowser & Co., Inc., S. F. 3
Breslauer, Nathan F. 138
Brevoort, Maurice J. 56
Bristol Co., The 37, 97, 126, 149, 172, 196, 199, 253, 277, 299
Brown Instrument Co., The 33, 34, 93, 222, 275, 280
Burlington Instrument Corp. 128
Burns, Kelvin 129
Burton-Rogers Co. 32, 65
Bushnell, B. O. 251, 280

Cambridge Instrument Co. 251
Central Scientific Co. 225
Clarostat Mfg. Co., Inc. 4, 5, 36, 198, 282
Clough-Brengle Co. 64, 92, 229, 230
Coleman Electric Co., Inc. 63
Colt's Patent Fire Arms Mfg. Co. 7
Consolidated Ashcroft Hancock Co., Inc., American Schaeffer & Budenberg Div. 6, 62
Continental Electric Co. 62
Cutler-Hammer, Inc. 91

Daniels Orifice Fitting Co. 224
Davies, Idris I. 261
DeWitt, W. H. 315
DeZafra, Carlos 135
Dietert Co., Harry W. 96
Dumont Laboratories, Inc., Allen B. 3, 65, 121, 178, 223, 228, 259
Dunn, Inc., Struthers 11, 62

Eagle Signal Corp. 151
Efkalin Co., The 65, 299
Electric Switch Corp. 5, 127
Electrocon Corporation 94
Electronic Control Corp. 250
Electronic Laboratory, The 278
Ellis, Charles A. 139
Everson Mfg. Co. 121

Fairbanks, Morse & Co. 93
Fairchild, C. Owen 305
Federal Products Corp. 174, 198, 252
Ferner Company, R. Y. 257
Ferranti Electric, Inc. 6
Fischer & Porter Co. 250
Fisher Research Laboratories 195
Fisher Scientific Co. 154, 179
Fish-Schurman Corp. 229
Fluid Meters, Inc. 97
Forstall, Jr., Walton 203
Foxboro Co., The 252
Friez & Sons, Inc., Julien P. 67, 120, 151, 173, 178, 199
Fry, E. M., Jr. 314
Fulton, John W. 3, 138, 241

Gary, Charles S. 316
General Combustion Corp. 255
General Electric Co. 9, 10, 33, 36, 37, 40, 90, 91, 121, 125, 128, 146, 147, 280, 299, 300
General Radio Co. 122, 256
Geophysical Instrument Co. 128
Gessford, R. K. 45
G. M. Laboratories, Inc. 276
Guardian Electric Mfg. Co. 34, 62

Haley, W. H. 307
Halldorson Co., The 200
Hancock Valve Div., Manning, Maxwell & Moore, Inc. 251
Hanson, Elmo E. 164
Harner, H. R. 154
Hatfield, J. E. 154
Hawley, Paul F. 164
H-B Instrument Co. 8, 301
H. D. Electric Co. 196
Heiland, C. A. 289
Heineken Machinery Corp. 150
Hiermeier, V. H. 25
Hickok Electrical Instrument Co., The 5, 10, 63, 93, 123, 151, 196, 201, 257, 274, 279, 301, 302
Hill, George H. 285
Howe Scale Co., The 93, 278

Ideal Commutator Dresser Co. 302
Illinois Testing Laboratories 94, 127, 252
International Register Co. 4
International Resistance Co. 174, 197, 230, 275

Jacobson, M. G. 84
Jeffrey Mfg. Co., The 197

Kettenring, L. R. 56
Klipfel Mfg. Co. 275
Kyropoulos, S. 185

Laboratory Equipment Co. 128, 223, 304
Laminated Metals Corp. 32
Lankes, L. Richard 108, 269, 314
Le Carbone Co. 125
Leeds & Northrup Co. 35, 123, 147, 195, 223, 256
Leitz Co., A. 153
Lindberg Engineering Co. 66
Logan, George H. 284
Long, R. H. 189

Marksson, Alfred A. 244
Marsh Corp., Jas. P. 67, 175, 304
Marston Co., C. A. 175
Mason-Neilan Regulator Co. 28
Mercoid Corporation 202
Meriam Co., The 227, 257
Mico Instrument Co. 7, 96, 176, 200
Miller Co., B. F. 148
Minneapolis-Honeywell Regulator Co. 175, 252, 254, 274
Minneapolis-Honeywell Regulator Co., Natl. Regulator Div. 256, 259, 303
Moon, Alfred G. 15
Moore, Coleman B. 242
Morey, Francis C. 157, 308
McDonnell & Miller 253

National Acme Company 174, 195
Newark Wire Cloth Co. 94
Newman, L. J. 239
Northern Equipment Co. 222

Ohmite Mfg. Co. 63, 179
Olken, H. 56, 315
Olson, Harold T. 219, 245, 316

Partlow Corp., The 302
Penn Electric Switch Co. 6
Permutit Co., The 7, 304
Pierce Watch Co. 33
Polarized Products Corp. 304
Polarizing Instrument Co. 151, 279, 298
Potter Co., The 173, 304
Production Control Machines Corp. 8
Production Instrument Co. 92, 224, 230
Pyrometer Instrument Co., The 250, 303

Ranco, Inc. 149
Raytheon Mfg. Co., Electrical Equipment Div. 198, 282
RCA Mfg. Co., Inc. 38, 39, 260, 298
Read Machinery Co. 147
Readrite Meter Works, The 10
Resch, Fritz 283
Richardson Scale Co. 67
Rimbach, Richard 249
Roller-Smith Co. 38
Rubicon Company 4
Ruggles Klingemann Mfg. Co. 63
Ruska & Co., Inc., Walter 64, 65
Ryan, William R. 220

Scheiber, E. J. 27, 188
Scherr Co., George 198, 281
Scientific Glass Apparatus Co. 3
Scott, H. H. 231
Shallcross Mfg. Co. 36
Shannon, P. B. 210
Sheffield Gage Corp. 127
Shobert, E. I. 185
Smith, Jr., Ed S. 75
Solar Mfg. Corp. 255
Spencer Lens Co. 127
Sprague Products Co. 64
Standard Electric Time Co., The 258, 277
Sticht & Co., Herman H. 91
Stickle, George W. 26
Stokes Machine Co., F. J. 281
Stromberg Electric Co. 304
Sundt Engineering Co. 90
Supreme Instruments Corp. 122, 226, 258, 282, 298, 303
Syntron Co., The 40

Taber Instrument Co. 227
Tagliabue Mfg. Co., C. J. 96, 226, 253, 298
Tamms Silica Co. 39
Taylor Instrument Companies 173, 251, 276
Teleweld, Inc. 300
Thwing-Albert Instrument Co. 7, 66
Tobe Deutschmann Corp. 35, 150, 259
Tozier, Robert W. 56
Triplett Electrical Instrument Co., The 8, 37, 97, 257, 276
Triumph Mfg. Co. 64
Trofimov, L. A. 27
Trumbull Electric Mfg. Co., The 6

United Cinephone Corp. 302

Van Keuren Co., The 150
Vickers, Inc. 97

Wade Instrument Co. 198, 225
Walser Automatic Timer Co. 301
Ward-Leonard Electric Co. 177
Water Level Controls Co. 176
Watts Regulator Co. 9
Weber, William 268
Wepsic, Stanley T. 138
Western Electric Co. 9, 250, 257
Westinghouse Electric & Mfg. Co. 91, 92, 122, 152, 146, 148, 179, 225, 276
Weston Electrical Instrument Corp. 38, 173, 176, 177, 255
Wheelco Instruments Co. 253
Wilcolator Co., The 33, 274
Williams, S. R. 12, 41, 68, 98, 133, 161, 182, 208, 237, 265, 286, 311
Wilmarth, H. J. 25, 84, 108
Wright, W. H. 245, 269
Wyatt, E. R. 138

Young, Douglass A. 180

BOOK REVIEWS

SUBJECT INDEX

Brown Flow Meter Engineering Handbook 140
Cathode Ray Oscillography 109
Dielectric Phenomena in High Voltage Cables 110
Direct-current Electrical Measurements 168
Directory of Trade Directories 270
Electrical Engineering Testing 109
Electrical Measurements and Measuring Instruments 112
Electrical Measurements—Precise Comparisons of Standards and Absolute Determination of the Units 269
Electron Tubes in Industry 192
Fundamentals of Vacuum Tubes 246
How to Find Metallurgical Information 114
Instruments Transformers—Their Theory, Characteristics and Testing 246
Le Travail des Verres d'Optique de Precision (Precision Optical Glass Working) 114
Lunettes et Telescopes—Theorie, Conditions d'Emploi, Description, Reglage 116
Manual on Geophysical Prospecting with the Magnetometer 272
The Mechanical Testing of Metals and Alloys 269
The Microscope 140
Practical Testing in Metal Industry 140
Principles of Electric and Magnetic Measurements 112
Radio Field Service Data 168
The Renaissance of Physics 142
Reports on Progress in Physics, Vol. II 140
Reports on Progress in Physics, Volume III 270
Telescopes and Range Finders 272
Tentative Code of Recommended Practices for Grinding, Polishing and Buffing Equipment Sanitation 269
Tentative Code of Recommended Practices for Testing and Measuring Air Flow in Exhaust Systems 269

AUTHOR INDEX

American Foundrymen's Association 269
Burns Organization 270
Chirardi, Alfred A. 168
Couder, Andre 116
Curtis, Harvey L. 269
Damerow, E. 140
Danjon, Andre 116
Darrow, Karl K. 142
Deve, Charles 114
Eastman, Austin V. 246
Feldmark, J. O. 140
Ferguson, Allan 140, 270
Foster, P. Field 269
Gage, Simon Henry 140
Gess, Louis 140
Golding, E. W. 112
Hague, B. 246
Henley, J. T. 109
Henney, Keith 192
Herr, A. 140
Joyce, J. Wallace 272
Koenig, Albert 272
MacGregor-Morris, L. T. 109
Parr, G. D. Aspinall 109
Rimbach, Richard 114
Robinson, D. M. 110
Schwerdtfeger, W. 168
Vigoureux, P. 112
Webb, C. E. 112